

Weather Information Database (WIDB) Information Technology System Architecture Document

Appendix B – Current NOAA and FAA Weather Systems

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NextGen Architecture and Infrastructure Development
WIDB IT System Architecture Document

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APPENDIX B – Current NOAA and FAA Weather Systems

1 Aviation Weather Concept of Operations

This section provides a brief overview of the concept of operations for aviation weather and various supporting organizations.

1.1 Introduction

Aviation weather is a joint effort between the National Weather Service (NWS), the Federal Aviation Agency (FAA), the Department of Defense (DoD), and other aviation-oriented organizations and third parties. This section describes these organizations and their respective component groups.

1.2 NOAA

The National Oceanic and Atmospheric Administration (NOAA) is an agency under the Department of Commerce (DoC). NOAA has six major divisions, of which is the NWS. The overarching purpose of NOAA is to conduct research and gather data about the global oceans, atmosphere, space, and sun, and applies this knowledge to science and service which touches the lives of all Americans.¹

1.2.1 NWS

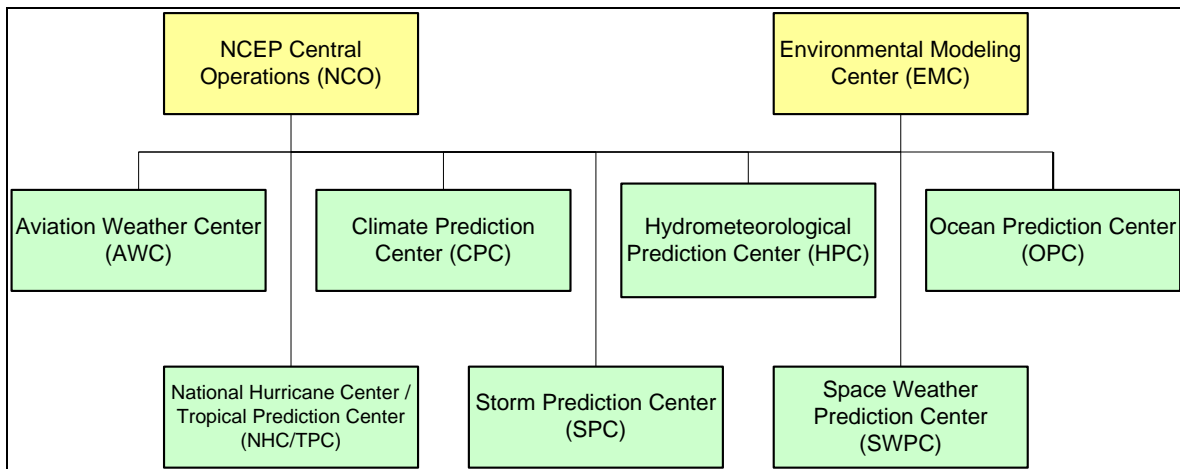
The National Weather Service (NWS) provides weather data, forecasts and warnings for the United States, its territories, adjacent waters and ocean areas for the protection of life and property and the enhancement of the national economy. NWS data and products are used among other government agencies, the private sector, the public and the global community. NWS has many constituent offices; the following are brief descriptions of offices that are generally associated with aviation weather.

1.2.1.1 NCEP

The National Centers for Environmental Prediction (NCEP) collect and analyze a large amount of meteorological data. NCEP runs numerous modeling algorithms on high-performance computers to create various model outputs and forecasts that are used by a wide variety of national and international offices. NCEP is a critical resource in national and global weather prediction and generates a large portion of NWS weather forecasts.

In Camp Springs, Maryland, NCEP's Central Operations (NCO) sustains and executes an operational suite of the numerical analyses and forecast model and prepares NCEP products for dissemination. The Environmental Modeling Center (EMC) develops and improves numerical weather, climate, hydrological and ocean prediction through applied research, modeling, and product development. Together, the NCO and EMC link together and provide infrastructure support to NCEP's seven Service Centers as depicted in the figure below.

¹ *Aviation Weather Services, Advisory Circular 00-45, page 1-1*



1.2.1.2 Aviation Weather Center (AWC)

Located in Kansas City, Missouri, the Aviation Weather Center (AWC) is a Meteorological Watch Office (MWO) for the International Civil Aviation Organization (ICAO). The AWC issues the following list of products to support air traffic controllers and the National Airspace System (NAS).

- SIGMETs
- AIRMETs
- Convective SIGMETs
- FAs
- Significant Weather Charts (low, middle, high)
- CCFP
- NCWF
- CIP
- FIP

1.2.1.3 WFO

The NWS Weather Forecast Office (WFO) is a local weather forecast office that produces a range of products. To support aviation, WFO's issue Terminal Aerodrome Forecasts (TAFs), as well as other aviation-oriented products. There are 122 WFO's in the US, all equipped with AWIPS and other dedicated hardware. All 122 WFO's AWIPS stations are connected to NWS headquarters National Capitol Region (NCR).

1.2.1.4 CWSU

CWSUs (Center Weather Service Units) are in place at ARTCCs (Air Route Traffic Control Centers) in order to deliver more timely weather information to Air Traffic Controllers. There are 21 CWSUs across the nation and are located within their respective ARTCCs. The FAA contracted National Weather Service (NWS) meteorologists to work at CWSUs to provide meteorological support at least 16 hours per day, seven days a week, 365 days a year.

The CWSU meteorologists prepare two products: a Meteorological Impact Statement (MIS) and a Center Weather Advisory (CWA).

- MIS – Details weather expected to impact the safe and efficient flow of air traffic within the Center airspace with a 2 to 12 hour period.
- CWA – A short term nowcast, pinpointing hazardous weather already causing an impact or expected to cause an impact within a 2 hour period.

The MIS is for planning purposes only, while the CWA is an in-flight advisory.

1.2.1.5 AAWU

The Alaskan Aviation Weather Unit (AAWU), located in Anchorage, AK, is responsible for the entire Anchorage Flight Information Region (FIR). The AAWU issues the following products for the airspace over Alaska, as well as its adjacent coastal waters.

- AIRMETs
- SIGMETs
- FAs
- Graphic Area Forecast
- Significant Weather Charts (low and mid-level, below 25,000ft)

In addition, the AAWU is also designated as the Anchorage Volcanic Ash Advisory Center (VAAC). The VAAC is responsible for Anchorage FIR and far eastern Russia; they issue Volcanic Ash Advisories (FVs) when needed.

1.2.1.6 HPC/SPC/TPC

The Hydrometeorological Prediction Center (HPC), Storm Prediction Center (SPC), and Tropical Prediction Center (TPC) are located in Camp Springs, MD, Norman, OK, and Miami, FL, respectively. The HPC creates specialized products in quantitative precipitation forecasts to five days, weather forecast guidance to seven days, real-time weather model diagnostics discussions and surface pressure and frontal analyses². The SPC provides tornado and severe weather watches for the CONUS along with a suite of hazardous weather forecasts and mesoscale guidance products². The TPC provides official NWS forecasts of the movement and strength of tropical weather systems and issues the appropriate watches and warnings for the CONUS and surrounding areas. It also issues marine products for the tropical Atlantic, Caribbean, Gulf of Mexico, and tropical eastern Pacific³.

1.2.2 NESDIS

NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) manages the US civil operational remote-sensing satellite systems, as well as other global information for meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences. NESDIS operates the United States

^{1 2 3} *Aviation Weather Services, Advisory Circular 00-45F*

Geostationary Operational Environmental Satellites (GOES) and Polar-Orbiting Environmental Satellites (POES), collects data from these platforms, and processes and disseminates the data. NESDIS data is used for operational weather forecasting.

1.2.3 FAA

The Federal Aviation Agency (FAA) provides a safe, secure, and efficient National Airspace System (NAS) that contributes to national security and the promotion of U.S aviation safety. As the leading authority in the international aviation community, the FAA responds to dynamic changes in user needs, economic conditions, and environmental concerns.

1.2.3.1 ATCSCC

The Air Traffic Control System Command Center (ATCSCC) mission is to balance air traffic demand with system capacity. This optimizes the efficiency of the NAS while minimizing delays. The ATCSCC utilizes the Traffic Management System, aircraft situation display, monitor alert, the follow-on functions, and direct contact with ARTCC and terminal radar approach control facility (TRACON) traffic management units to manage flow on a national level.

Because weather is the most common cause for air traffic delays, the ATSCC is supported by CWSU meteorologists to provide them with meteorological information that pertains to national air traffic flow management and any other significant weather phenomena that can effect aviation for their area.

1.2.3.2 ARTCC

An Air Route Traffic Control Center (ARTCC) is a facility responsible for controlling Instrument Flight Rules (IFR) aircraft en route in a particular volume of airspace at high altitudes between airport approaches and departures.

En route controllers become familiar with pertinent weather information and stay aware of current weather information needed to perform air traffic control duties. En route controllers advise pilots of hazardous weather within the controller's assigned sector(s).

1.2.3.3 ATCT

An Air Traffic Control Tower (ATCT) is a terminal facility that uses air/ground communications, visual signaling, and other devices to provide air traffic control services to aircraft operating in the vicinity of an airport or on the movement area. It authorizes the takeoff and landing of airplanes at the ATCT's respective airport.

1.2.3.4 FSS

Flight Service Stations (FSSs) and Automated Flight Service Stations (AFSSs) provide en route weather, pilot weather briefings, receive and process IFR and Visual Flight Rules (VFR) flight plans, relay ATC clearances, and issue Notices to Airmen (NOTAMs). They also assist lost aircraft and aircraft in emergency situations, and perform VFR search and rescue services.

1.2.3.5 Phases of Flight

For every airplane that occurs, there is a considerable amount of planning that is done before the flight, during the flight, and after the flight. There are five stages that are involved in flying an airplane: Preflight, Terminal, En Route, Terminal, and Post Flight.

The Preflight stage occurs before the plane is on the runway, the Terminal stage covers both takeoff and landing, En Route covers when the plane is not on the ground, and the Post Flight stage analyzes the overall flight. The En Route stage can be broken down to departure, cruise, metering/descent, and final approach. All these stages need specific type of weather products to perform their respective strategic/tactical planning.

2 NOAA Weather Systems

This section begins with a brief overview of the concept of operations for aviation weather and various supporting organizations then describes the current system level architecture for major NOAA weather systems that may be involved in the Cube. The following sections detail the general concept of operations for each system as well as their technology architecture/information flows.

2.1 ADDS

2.1.1 Concept of Operation

The Aviation Digital Data Service (ADDS) makes available to the aviation community digital and graphical analyses, forecasts, and observations of meteorological variables through the Internet. Developed as the data distribution component of the Aviation Gridded Forecast System (AGFS), ADDS is operated by the NWS National Centers for Environmental Prediction (NCEP) Aviation Weather Center (AWC) in Kansas City. ADDS is a joint effort with the National Center for Atmospheric Research (NCAR) Research Applications Laboratory (RAL) and the NOAA Earth System Research Laboratory (ESRL) Global Systems Division (GSD) with funding provided by the FAA.

Data available from ADDS include:

- METARs
- TAFs
- PIREPS
- AIR/SIGMETs
- Satellite
- Radar
- Analysis & Prognostic Charts
- Graphical wind & temperature charts
- National Convective Weather Forecast
- Current & Forecast Icing Potential
- Graphical Turbulence Guidance
- Flight Path Tool

Many of the products are based on the Rapid Update Cycle (RUC) operational weather prediction system operated by NOAA/NCEP. ADDS has several Java tools available online, including the new Flight Path Tool offering users an interactive tool to display various aviation product and map overlays.

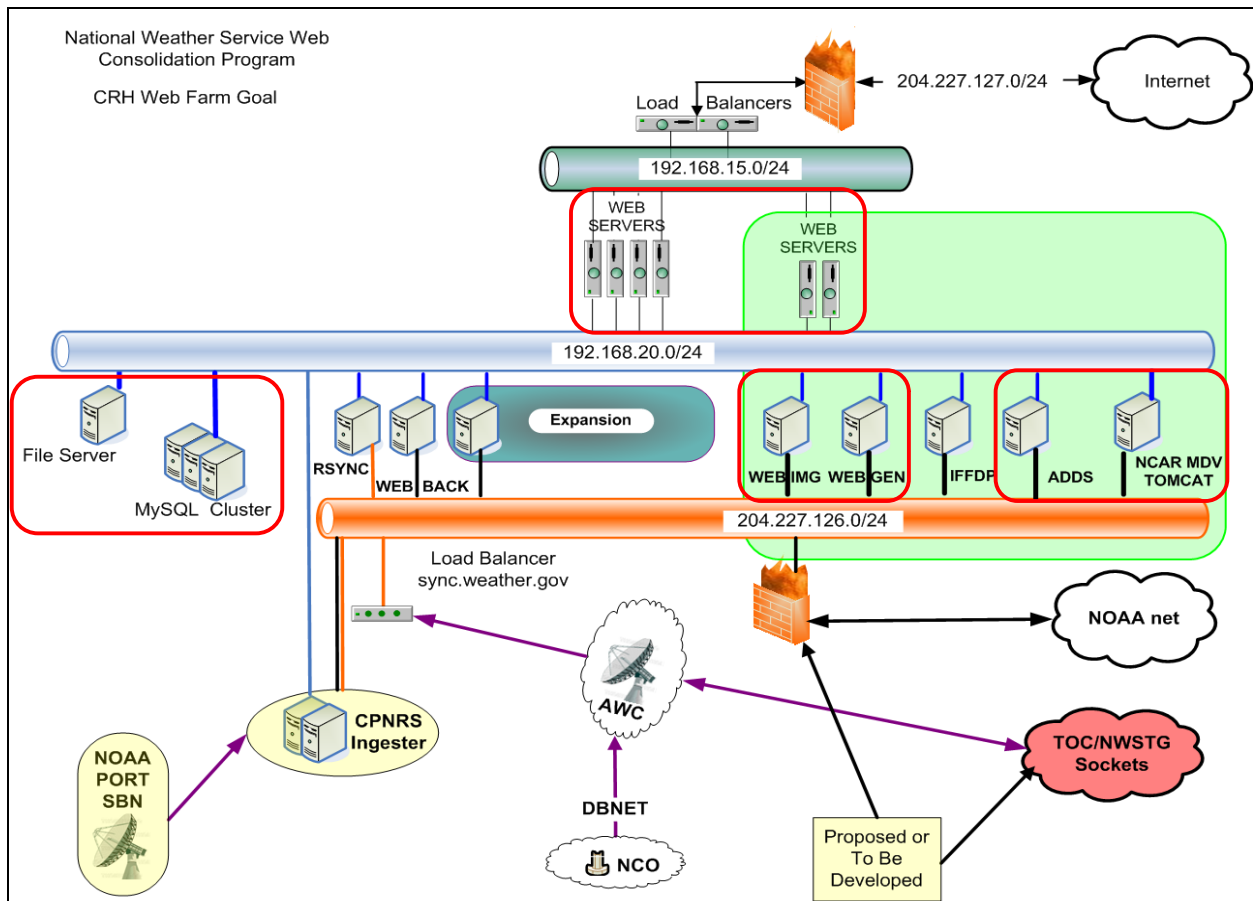
Primary users of ADDS include pilots, dispatchers, aviation weather briefers, and meteorologists.

2.1.2 Technology Architecture / Information Flows

The ADDS web dissemination channel is encompassed in the Consolidated Aviation Web Services (CAWS), which is currently being implemented in the Consolidated Internet Farms (CIF). Both of these infrastructure systems are covered in later sections. As part of this effort, ADDS is being re-architected to support greater scalability and to separate web services, content generation services, file services, data acquisition services and database services into separate computer systems. ADDS interfaces include PHP for page generation, static displays, MySQL request and display response, and java tools allowing interaction and customization. Associated architecture components include a MySQL database cluster, WEBGEN web page generator, WEBIMAGE web image generator, and an NCAR MDV Tomcat server for gridded data. This architecture as implemented at the Central Region CIF is depicted in the figure below.³ Note that the components related directly to ADDS are outlined with red boxes.

The data collected from the NCEP/AWC includes the NCEP operational suite. NCEP utilizes ADDS and NOMADS as dissemination methods, as well as sending data directly to the NWSTG. WCS/WFS technologies are used to communicate between participating parties.

³ ADDS presentation; C. Bruce Entwistle, Science and Operations Officer, Aviation Weather Center; NOAA System of Systems Workshop, October 7, 2009.



2.2 AWIPS II

2.2.1 Concept of Operation

The Advanced Weather Interactive Processing System (AWIPS) is the system used by NOAA/NWS to analyze and disseminate operational weather data, including time-sensitive, high-impact warnings. AWIPS II consists of the current baseline functionality of the current AWIPS system, but migrated to a Services Oriented Architecture (SOA). Refer to Section IV for further details on SOA. AWIPS II will be structured to leverage open source software, which has become a viable alternative to COTS software.

AWIPS II is being designed from the ground up to ensure efficient operations, maintenance, and expansion through the use of SOA principles. The new architecture will provide a software environment that meets the NWS' continuously evolving mission requirements. AWIPS II is being designed as a "black-box" conversion from AWIPS with no loss of functionality.

AWIPS II will be delivered in two phases. Phase I (FY06-011) will migrate the WFO and RFC AWIPS system (AWIPS I) to the newly developed SOA infrastructure. This will be achieved incrementally through a series of task orders issued to the prime contractor, Raytheon. Phase II (FY09-12) will extend the AWIPS II SOA to create a seamless weather enterprise network architecture spanning all levels of NWS operations. This extension consists of four separate components:

- National Center AWIPS (NAWIPS) migration into AWIPS SOA
- Delivery of Thin Client to WFOs, CWSUs, and Incident Meteorologists (Fire Weather, backup support for RFCs and National Centers)
- Integration of Weather Event Simulator (WES)
- Community Hydrological Prediction System (CHPS) integration into AWIPS SOA

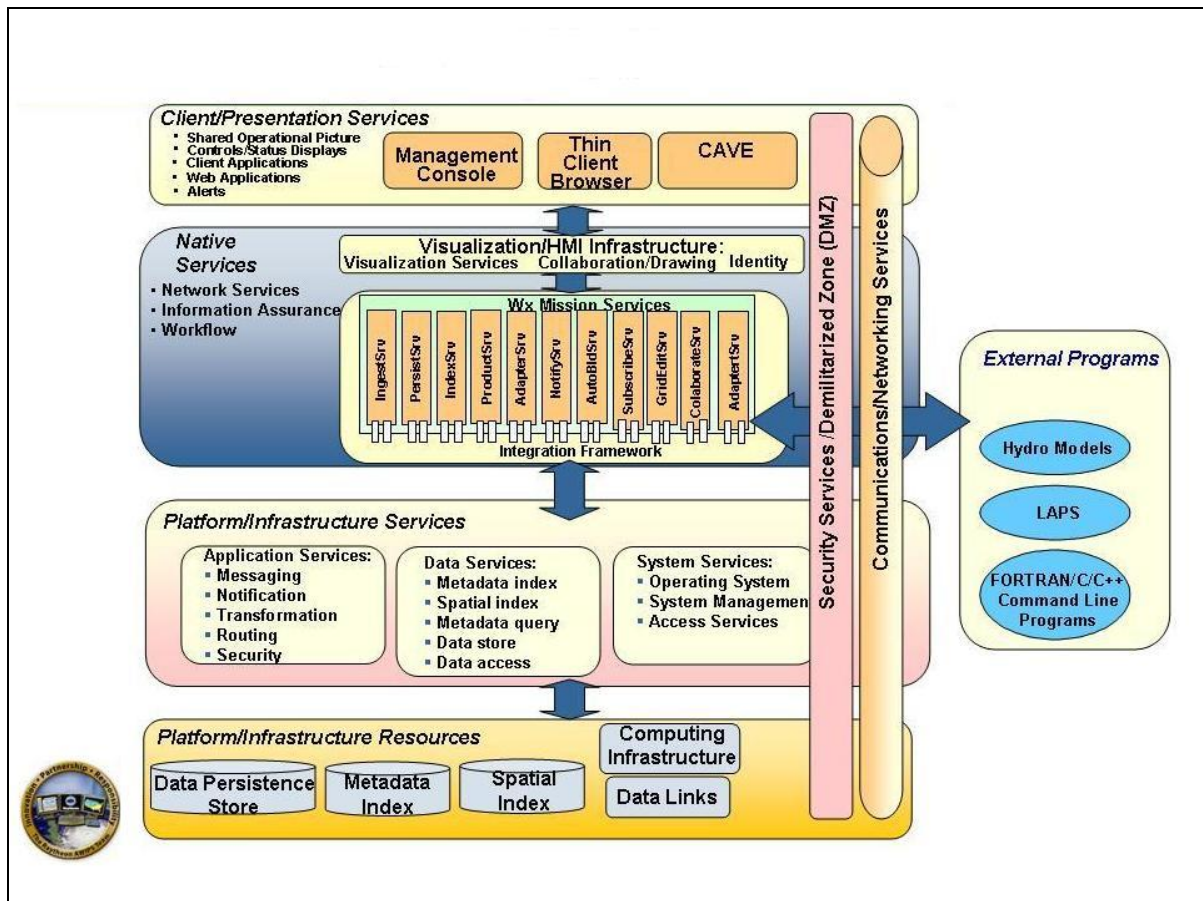
The extension AWIPS-II architecture throughout the weather enterprise infrastructure enables meteorological and hydrological operations for all components of the National Weather Service (NWS) (national centers, river forecast centers, weather forecast offices to weather service offices) and the associated training to support operations.

Phase III (FY09-15) will consist of Enterprise Level Enhancements that include:

- Data delivery enhancements (“smart push – smart pull” data access)
- Integrated visual collaboration
- Information generation enhancements
- Visualization enhancements (developing new user interface standards and three dimensional visualization)

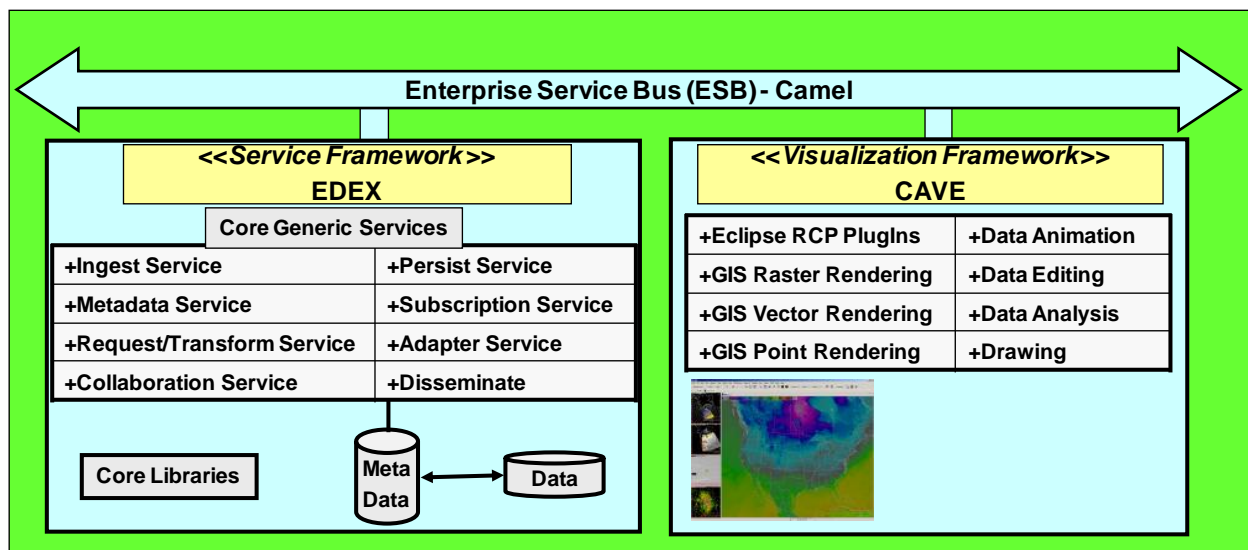
The logical view of AWIPS II is presented in the figure below.⁴

⁴ *** need Raytheon reference



2.2.2 Technology Architecture / Information Flows

The AWIPS II architecture is being based on plug-in extensible services and is based on JAVA and open source projects enabling AWIPS II to be platform and OS independent. The reference architecture is shown below:



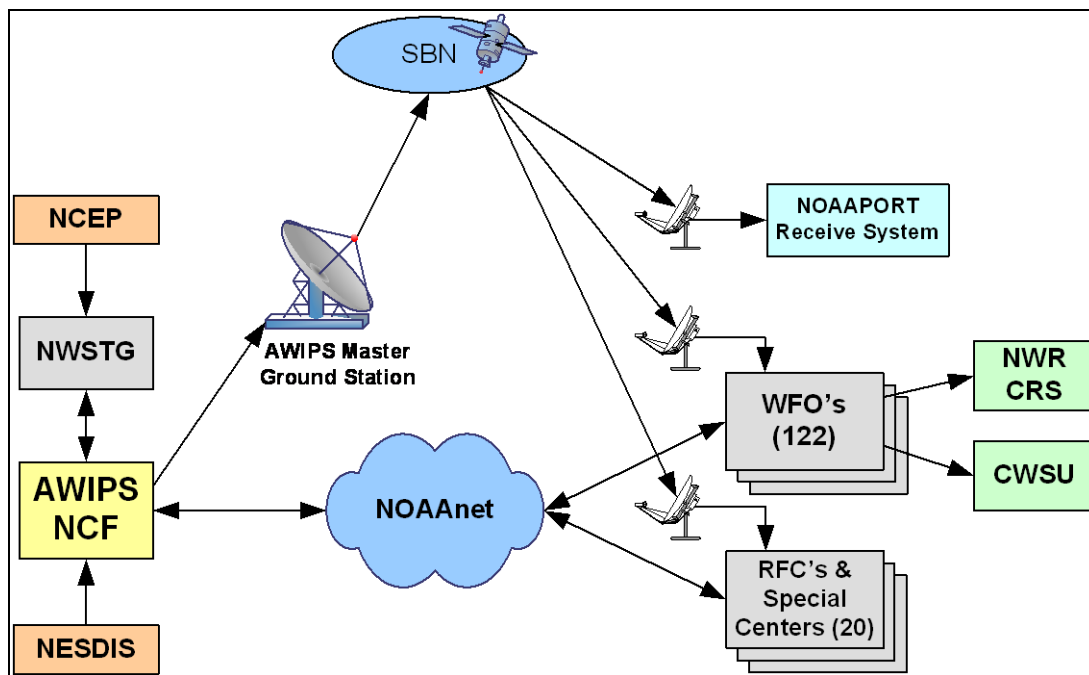
The following is a reference table of AWIPS II open source tools:

CAMEL + Spring	Enterprise service bus and dependency injection container for SOA services (decoupled services)
activeMQ	Java messaging provider with clustering and JMS tunneling over HTTP
PostgreSQL	Relational database for storing Metadata from Data plug ins and spatially enables ingested data
PostGIS	Spatially enables PostgreSQL
Hibernate3	Relational RDBMS to Java Object mapping
GeoTools	Enables GIS capabilities and map projection framework
JOGL	Java API to OpenGL enables Gaming level visualization performance
HDF5	High performance file persistence of large data sets such as satellite, radar, and parsed point data
JAVA + ANT	Primary programming language and software build framework
Python + numPY	Data transform scripting languages with high performance math library
Apache Velocity	Provides a mechanism for automatic text product generation
Eclipse RCP	Plug In driven visualization framework
OpenFire	Real time collaboration server based on XMPP
Batik	Scalable Vector Graphics (SVG) used for plots
Apache Thrift	Binary service message transfer serialization
Jetty	Web application container

The information flow for AWIPS II is not significantly different when compared to AWIPS. The external systems connected to AWIPS II should not notice a change; AWIPS II is a self-contained, internal change. Once the migration from the AWIPS Frame Relay WAN to NOAAnet is complete, AWIPS II will continue to use NOAAnet as the primary WAN infrastructure between the WFOs, RFCs, and Special Centers.

Under AWIPS II, the National Control Facility (NCF) will continue to ingest satellite data from NESDIS and forecast and model data from NCEP through the NWS Telecommunications Gateway. The NCF also receives forecast and observational data from the WFOs, RFCs, and Special Centers, which will be through NOAAnet. After processing and assembling ingested data, the NCF disseminates the data via the AWIPS Master Ground Station through the NWS Satellite Broadcast Network (SBN) to satellite receivers to the WFOs, RFCs, and Special Centers, as well as to external users through the NOAAPORT service. Data will also be sent to the WFOs, RFCs, and Special Centers through NOAAnet (in place of the current AWIPS WAN). The WFOs further disseminate the data to the NOAA Weather Radio (NWR) Console Replacement System (CRS) and to the CWSUs operating at 21 FAA Air Route Traffic Control Centers (ARTCCs).

The NCF also sends data back the NWSTG for dissemination by other systems, such as EMWIN.



AWIPS II information flow

AWIPS II primary standards and formats listed below:

- Ingested Data Formats
 - GRIB1/GRIB2 – Gridded data
 - NetCDF3 – Support AWIPS I/II interoperability
 - BUFR – Observational Data, e.g., soundings
 - METAR, SHEF – Surface and hydrological data
 - GINI – Satellite Imagery
 - OPRG L3 – Radar Imagery
 - Text Messages – Text products
- Data Store Formats
 - PostGRES – Metadata and select data type store, e.g., text
 - HDF5 – Binary store for grids, imagery and select observations
- Product Distribution
 - NetCDF3 – NDFD Grids
 - ASCII Text – Text products

2.3 GIS Systems

2.3.1 Concept of Operation

A Geographic Information System (GIS) is used to display geographic data on a map. It translates the values in databases and spreadsheets, and places the information on a map. GIS is a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. Visualizing data on a map is important because it allows the user to understand the information in ways not possible with just analyzing values in a database or spreadsheet. Better decisions can be made with the inclusion of geography and spatial analysis. GIS allows the user to view weather information with much greater detail.

GIS utilizes shapefiles to project them on top of geographic layers. A shapefile is a digital vector storage format for storing geometric location and associated attribute information. A shapefile consists of multiple files, some of which are mandatory and others are optional. A shapefile works by relating shapes (points/lines/polygons) to data attributes; this method can create an infinite number of representations for geographic information. The NWS basemaps are available as shapefiles.

Keyhole Markup Language (KML) is also used by a variety of GIS applications (See Appendix C for more details on KML).

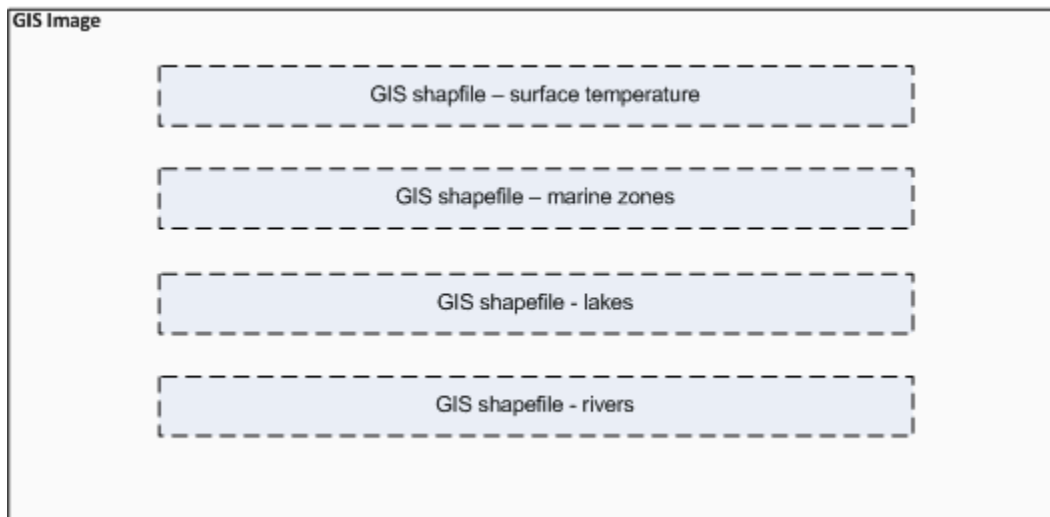
A GIS program (viewer) is needed to interpret/display shapefile information. Some GIS applications include:

- NASA World Wind
- GoogleEarth
- ESRI's ArcGIS Explorer
- FME (Feature Manipulation Engine)
- ArcGIS extension

2.3.2 Technology Architecture / Information Flows

GIS applications can be installed locally on a computer, or can be accessed via web services over the open Internet. GIS applications accessed over the Internet utilize OGC standards such as WFS, WCS, WMS, and KML.

While GIS software can vary between applications, their functionality remains consistent. Shapefiles are loaded into GIS applications as layers over a basemap. Resolution of the map is as good as the resolution of the shapefiles. The diagram below depicts the construction of a GIS image.



The above example GIS image is composed of several shapefiles (surface temperature, marine zones, lakes, rivers) layered with transparent backgrounds all over a main basemap.

2.4 IOOS

2.4.1 Concept of Operation

NOAA is in the process of analyzing systems engineering and development approaches for implementing the national Integrated Ocean Observing System (IOOS) Data Management and Communications subsystem (DMAC).⁵

The NOAA IOOS mission is to:

Lead the integration of ocean, coastal, and Great Lakes observing capabilities, in collaboration with Federal and non-federal partners, to maximize access to data and generation of information products to inform decision making and promote economic, environmental and social benefits to our nation and the world.

The U.S. IOOS is a coordinated network of people and technology that work together to generate and disseminate continuous data, information, models, products, and services related to coastal waters, ecosystems, Great Lakes, and oceans. The oceans are global, dictating that IOOS must address local coastal and global scales through two interdependent components, a national coastal component and a global ocean component.

At this time, it is not clear what if any role IOOS will play directly in the development and operations of the 4-D Weather Cube, however, many of the guiding principles of data aggregation, transformation, and formatting and transport standards are quite similar in nature to efforts underway to implement the Cube. Development of IOOS is consistent with that of a System of Systems similar to planned NextGen Cube development. As such, it may be possible to leverage the same standards and federated

⁵ This section was excerpted from a recent IOOS RFI posting on FedBizOpps.

registry/repository across both programs, which could result in better interoperability and data sharing among participating systems.

2.4.2 Technology Architecture / Information Flows

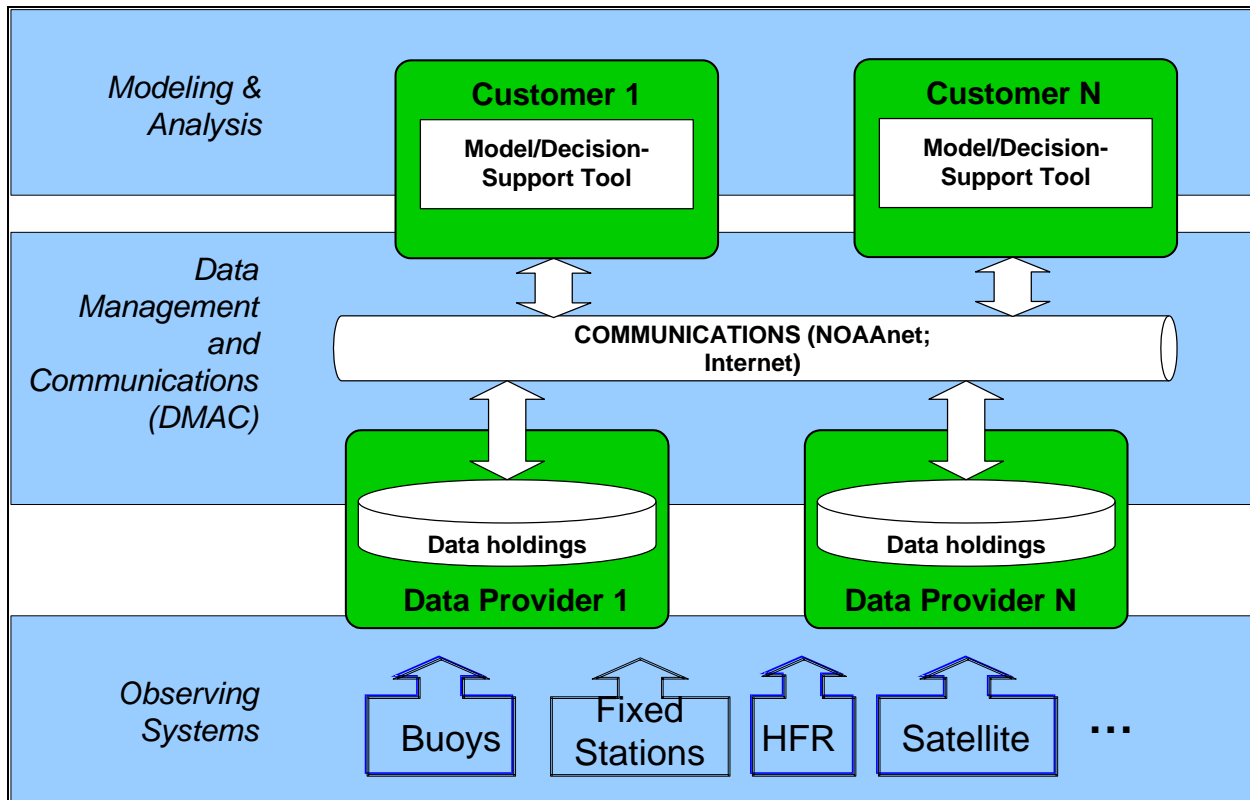
IOOS will integrate existing (legacy) and new observing systems, data, organizations, and products. IOOS will (1) efficiently link environmental observations, data management and communications, data analyses, and models; (2) provide rapid access to multidisciplinary data from many sources; (3) supply data and information required to achieve multiple goals that historically have been the domain of separate agencies, offices, or programs; and (4) involve crosscutting partnerships among federal and state agencies, private-sector entities, and academic institutions.

IOOS will provide data to modeling systems and modelers. IOOS data will allow modelers to increase the data sets used in models, incorporating new and additional data into algorithms, enabling the development of new models and algorithms, and to increase quality control, comparing data expected to determine whether data fall within expectations or require additional review.

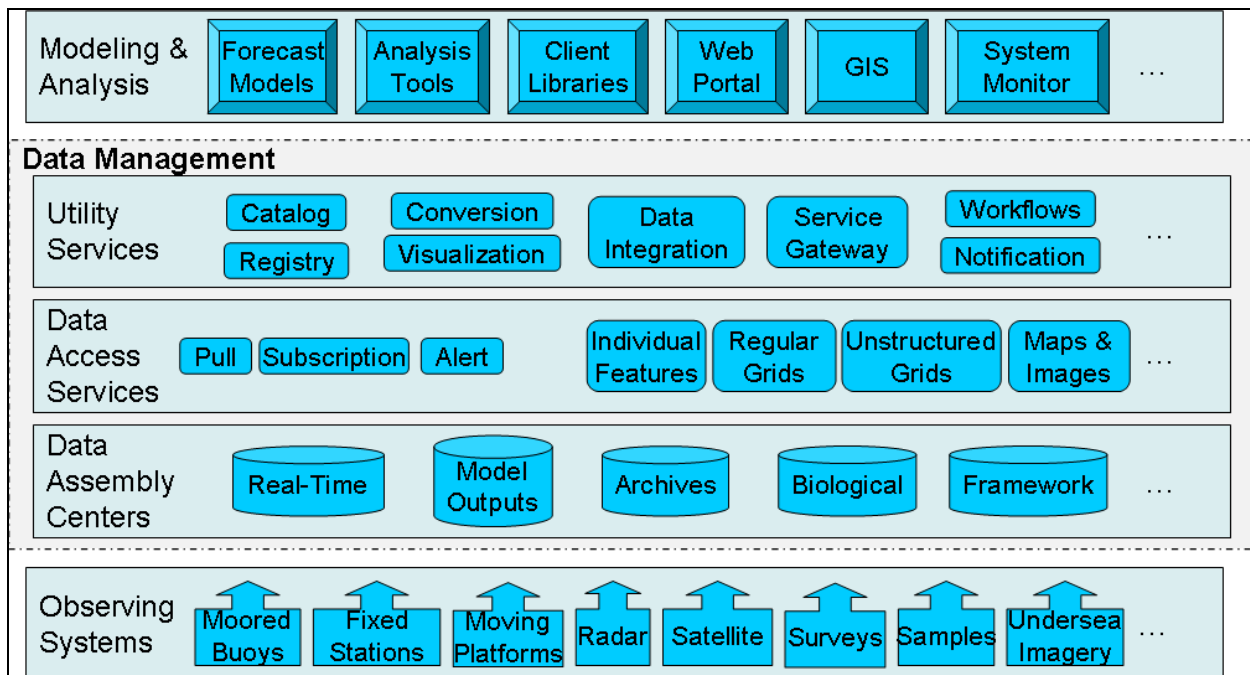
IOOS will provide mechanisms for aggregating (and buffering) data streams over useful spans of time and space. Data aggregation is any process in which a data set is generated by joining in some manner data held in more than one data set, possibly in more than one file, possibly at more than one site. In this manner data are replicated, not restructured.

A high level system overview of IOOS is presented in the figure below.

High Level Systems Overview of IOOS



A component view of IOOS is depicted in the following figure:



The 'Data Access Services' box in the above diagram represents the available methods for users to access data. The data is separated by data type: In-situ, regular grids, and images of data. For each data type there is an associated web service used to subset data both temporally and spatially. The figure below depicts these relationships.

Data Type	Web Service	Encoding
In-situ features (buoys, piers, floats, ships, ...)	OGC Sensor Observation Service (SOS)	XML based on OGC Observations and Measurements (O&M)
Regular Grids (radar, satellite, model outputs)	OpenDAP and/or OGC Web Coverage Service (WCS)	NetCDF using Climate and Forecast (CF) conventions
Images of data (all types)	OGC Web Map Service (WMS)	GeoTIFF, PNG etc. -possibly with standardized styles

Furthermore, the data access services for IOOS and the services involved with NextGen are based on OGC standards, which make them strong candidates for compatibility.

2.5 Lightning Data Services

2.5.1 Concept of Operation

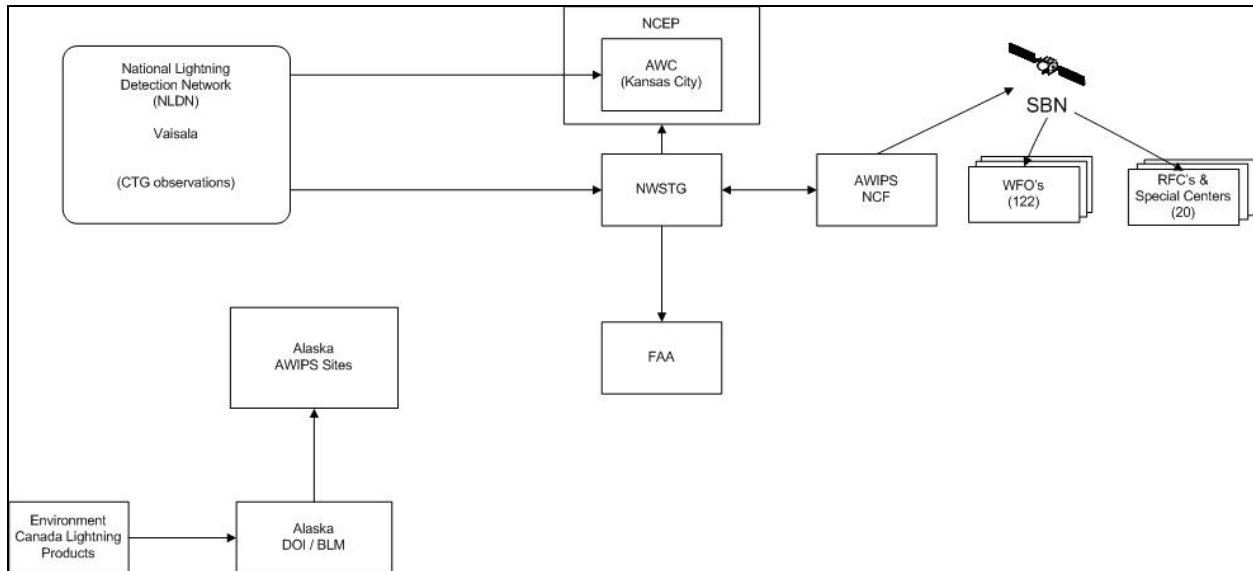
At this point NOAA does not have its own lightning data network. NOAA purchases lightning data from third-party vendors. GOES-R will be launched with a lightning sensor (approximately 2015 timeframe), which will be the first ever NOAA-provided lightning data. Currently, NOAA receives lightning from three different sources: Vaisala, Alaska DOI/BLM (Department of Interior / Business Land Management), and Mesonets.

Vaisala is the primary source of lightning data for the CONUS. Vaisala owns and operates the National Lightning Detection Network (NLDN). The NLDN observes a variety of lightning phenomena such as cloud-to-ground strokes, cloud-to-cloud strokes, cloud-to-air strokes, etc. The NWS only receives CTG (cloud-to-ground) observations. The DOI/BLM provides data coverage for Alaska and receives Canada's data, while the Mesonets is very limited in geographical coverage and not operationally guaranteed, NOAA collaborates on at least one lightning-sensor mesonet over the mid-Atlantic region.

2.5.2 Technology Architecture / Information Flows

Refer to the figure below for the current information flow of lightning data into to the NWS. The NLDN distributes its lightning data to the NCEP/AWC and the NWSTG. The data sent from Vaisala is encrypted.

The AWC uses the lightning data for its own internal uses, and the NWSTG is used as a distribution system to the AWIPS NCF and FAA systems. The AWIPS NCF collects lightning data from NLDN then transmits it to users via NOAAPort/SBN. The Alaska AWIPS sites receive lightning data for its area, as well as Canadian lightning products through the DOI/BLM.



2.6 Meteorological Assimilation Data Ingest System (MADIS)

2.6.1 Concept of Operation

MADIS was established in 2001 to prototype new access, integration, quality control, and distribution techniques for real time observation data with the goal of offering easy access to quality-controlled data from a wide variety of observing infrastructures. The system is being developed and operated by NOAA's Earth System Research Laboratory (ESRL) Global Systems Division (GSD) and has recently passed OSIP Gate 3. Initial Operating Capability (IOC) is expected in Q3 FY10 and Full Operating Capability (FOC) is expected in Q3 FY11.

MADIS provides ingest, integration, automated quality control (QC), and distribution support for both NOAA and non-NOAA observations. The MADIS data portfolio includes the following observational data:

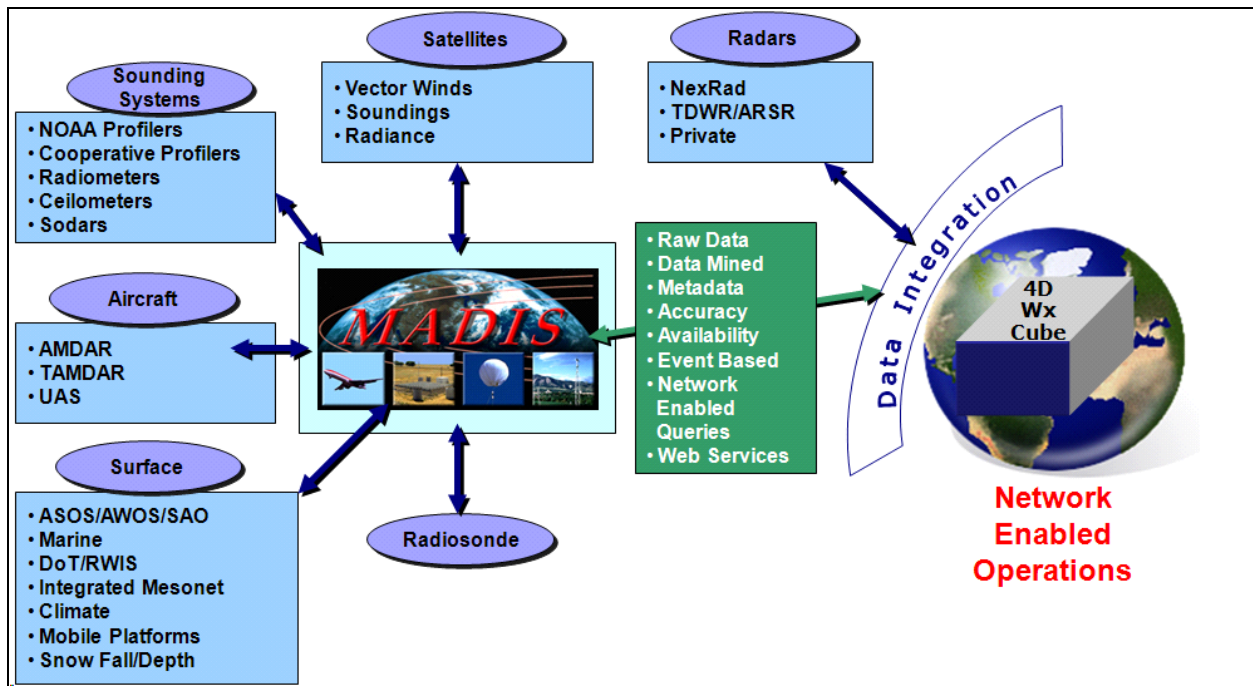
- Meteorological Surface
 - Meteorological Aviation Reports (METARs) (standard)
 - High Frequency METAR (experimental)
 - Surface Aviation Observations (SAO)
 - Maritime
 - Modernized NWS Cooperative Observer (aka NERON)
 - UrbaNet

- Integrated Mesonet - Observations from local, state, and federal agencies and private mesonets
- Radiosonde
- NOAA Profiler Network
- Hydrological Surface
- Automated Aircraft
 - Automated Aircraft Reports (MDCRS, AMDAR, TAMDAR)
 - Profiles at Airports
- Multi-Agency Profiler
- Radiometer
- Satellite Wind
 - NOAA GOES Operational 3-Hour
 - NOAA GOES Experimental 1-Hour
- Satellite Sounding (NOAA POES)
- Satellite Radiance (NOAA POES)
- Snow
- Weather In-Situ Deployment Optimization Method (WISDOM) Balloon Wind

MADIS improves observational functionality for: enhancing forecaster situational awareness, reducing data access costs for Forecast Offices, supporting higher-resolution global and regional data assimilation systems, and improving the NDFD. MADIS performs static and dynamic quality control on the observations, converts them into common formats, and makes these data available to the enterprise via a web-based interface. Since some of the data are proprietary, different distribution categories have been set up to handle restricting these datasets, which include some of the mesonets and automated aircraft data. In general, no restrictions apply to government agencies supporting forecasting operations, or to research and educational organizations or institutions. End users of MADIS include NOAA line offices, other Federal agencies, the private sector, and various universities.

A high-level overview of the planned post-FOC relationship of MADIS with data sources and the 4-D Weather Cube is shown below:⁶

⁶ Drawing was taken from *MADIS Program Review - Follow-up* presentation given by J.C. Duh, Chief, Programs and Plans Division, Office of Science and Technology, April 8, 2009



2.6.2 Technology Architecture / Information Flows

MADIS is being developed and operated at GSD with the plan to migrate primary operations to the NWSTG Telecommunications Operations Center (TOC) while maintaining a physical backup system at GSD post-FOC.

Access to data in MADIS is achieved through the Internet via the following:

- ftp
- LDM
- OPeNDAP
- Text/XML Viewer account (for the surface observation datasets only)

MADIS subscribers can receive real-time data or obtain access to on-line storage of saved real-time data via the following:

- ftp
- OPeNDAP
- Text/XML Viewer account (for the surface observation datasets only)

MADIS also includes an Application Program Interface (API) that provides users with easy access to the observations and quality control information. The API allows each user to specify station and observation types, as well as QC choices, and domain and time boundaries.

Additional services are provided so that all MADIS data files are directly compatible with AWIPS displays and applications without the use of the MADIS API software, and without the need to change AWIPS

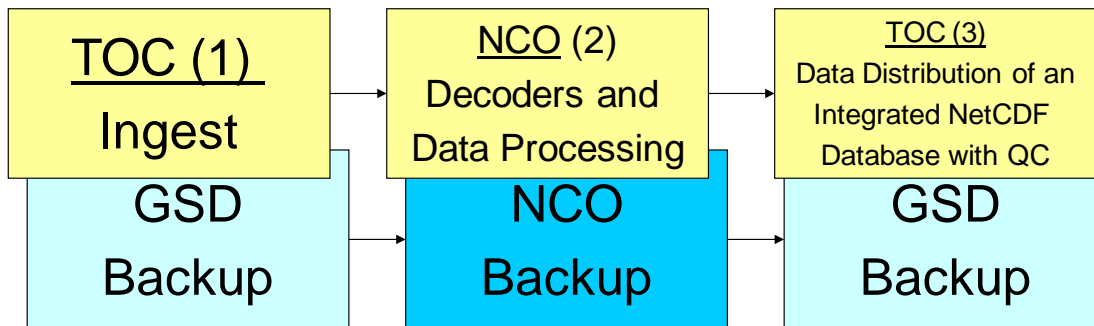
software to handle new datasets. MADIS output files are also compatible with AWIPS-like display systems such as FSL's FX-Connect and FX-Net, and the analysis software provided by the Local Analysis and Prediction System (LAPS) and the Weather Research and Forecasting (WRF) Model 3D-Variational (3DVAR) Data Assimilation System. They have also been used to initialize the Advanced Regional Prediction System (ARPS), MM5, and Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPSTM) forecast models. The output files for all MADIS datasets are available in uniform formats with uniform quality control structures within the data files.

The functional components of the MADIS architecture consist of the following:

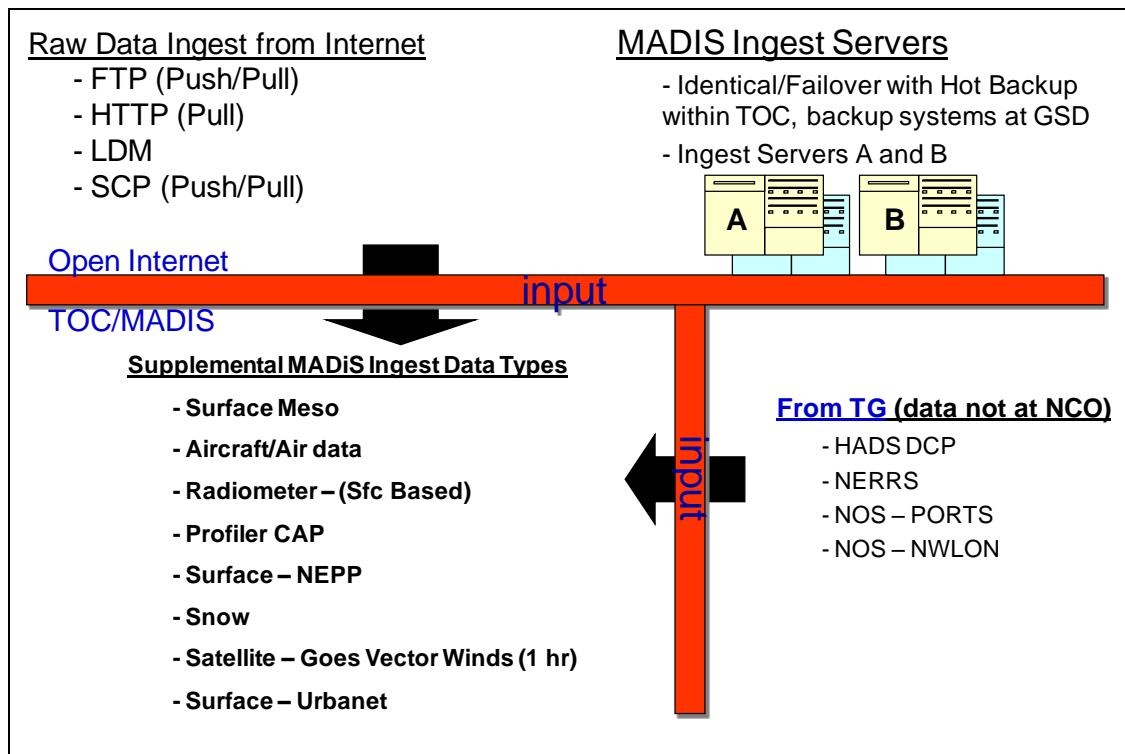
- Observational Ingest
- Processing
 - decoding
 - integration
 - quality control
- Distribution and Web Services

This functional architecture and the associated data flows are presented on the following several pages. This representation represents the planned end state of MADIS and was also taken from the MADIS Program Review - Follow-up presentation given by J.C. Duh, Chief, Programs and Plans Division, Office of Science and Technology dated April 8, 2009. The centers involved in hosting the processing servers are the NWS Telecommunications Operations Center (TOC), ESRL's GSD, and NCEP Central Operations (NCO). Plans for improvement of products include: advanced data query and web services, expanded metadata fields, additional datasets, and improved and expanded observation QC and station monitoring. MADIS also hopes to support the OGC Web Feature Service and ISO Metadata guidelines.

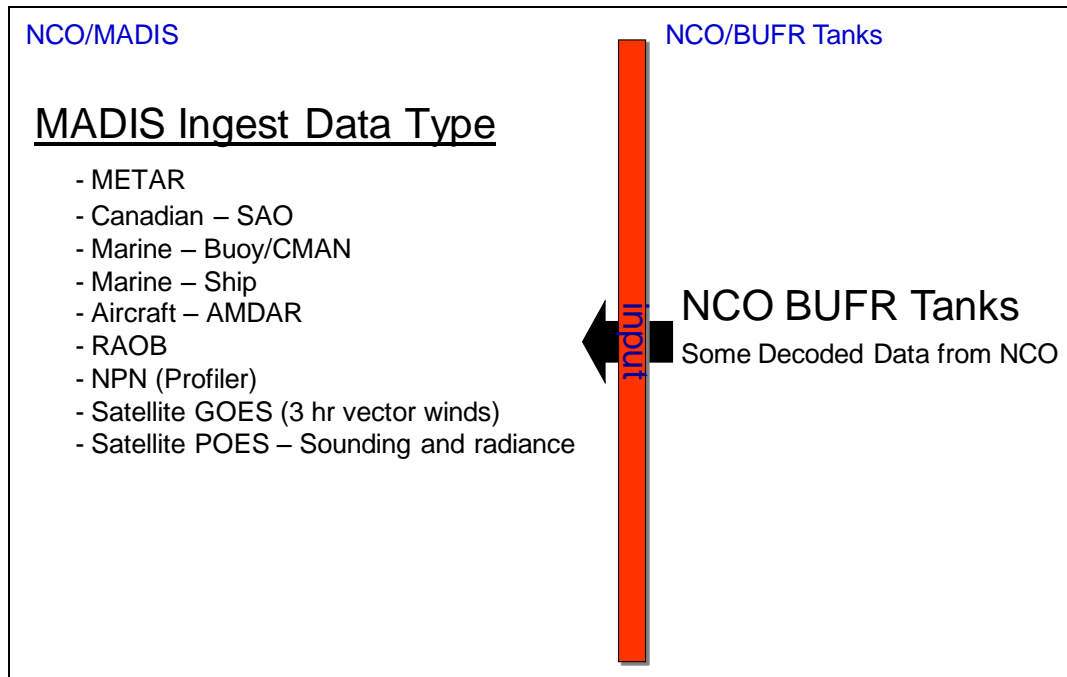
Basic MADIS Hardware Systems Locations



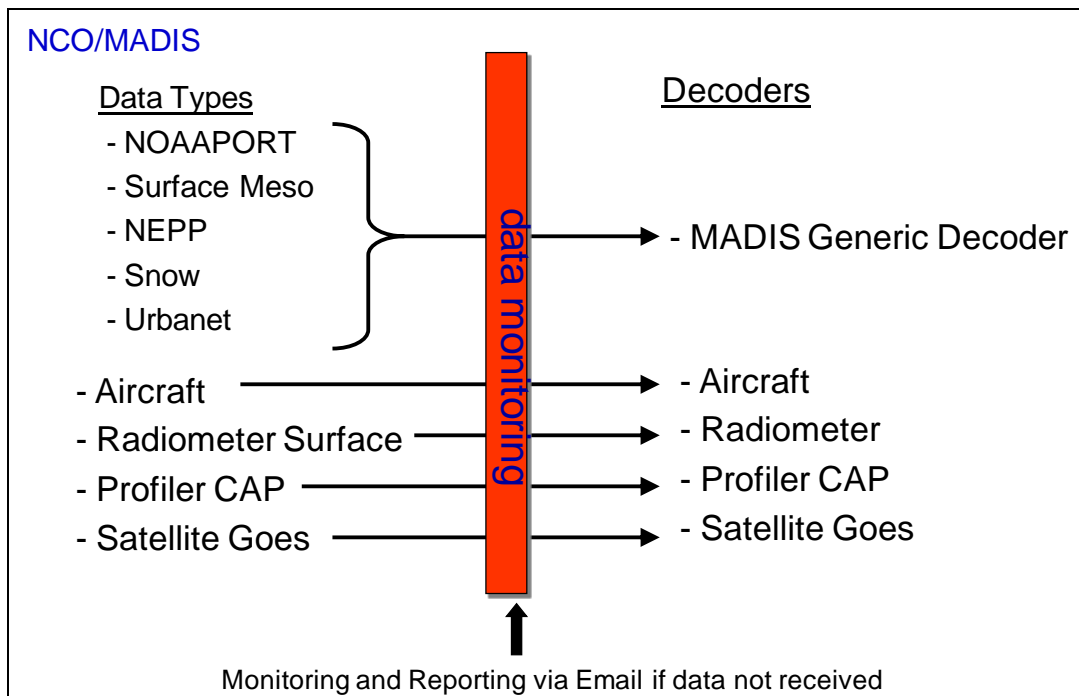
TOC/MADIS Data Ingest (1)



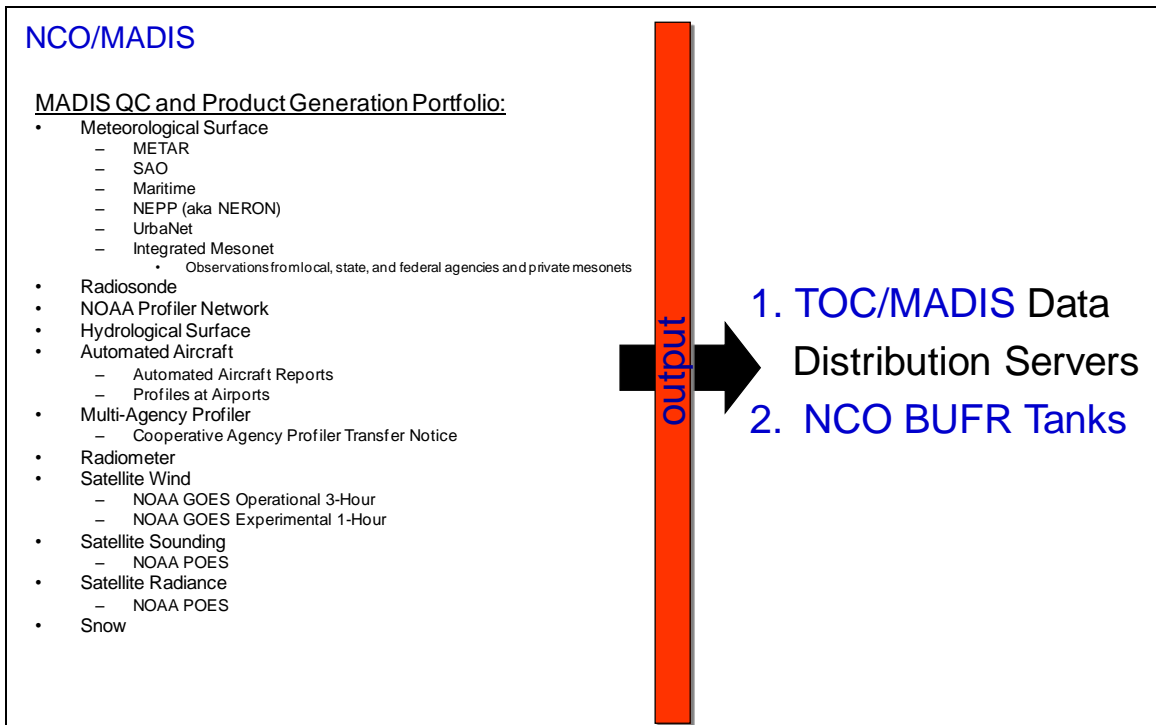
NCO Decoders (2a) – Leverages existing decoders



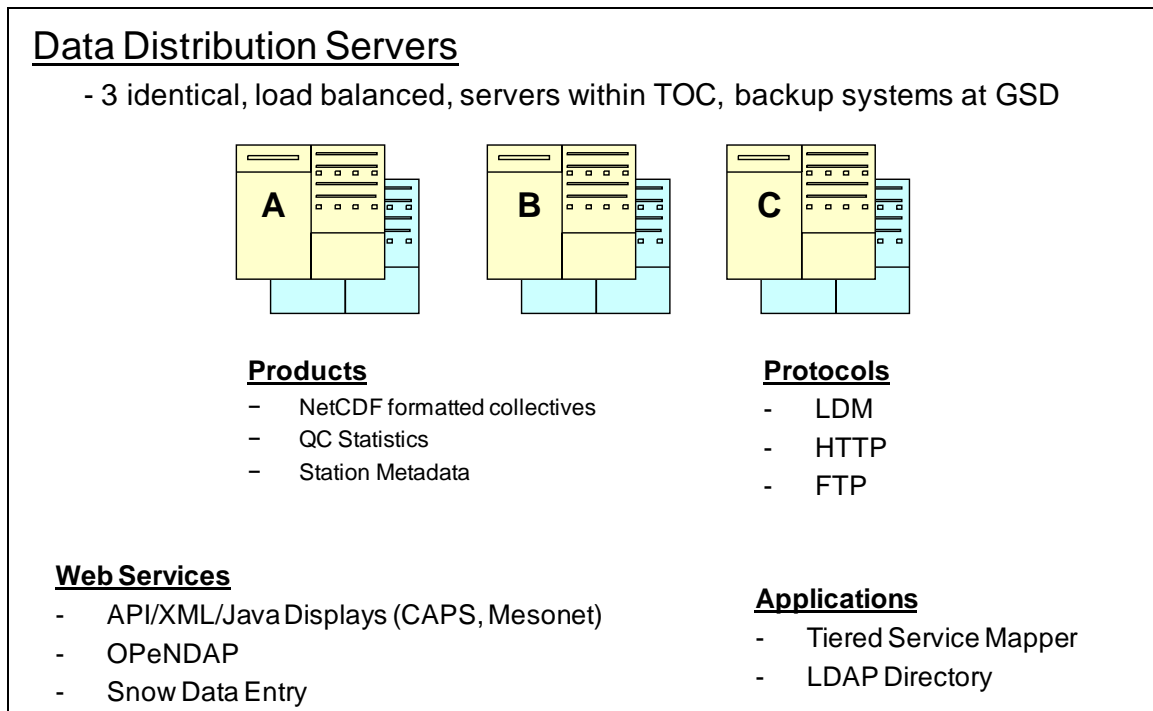
NCO/MADIS Decoder Types (2b)



NCO/MADIS Data Processing (2c) -- "MADIS Products"



TOC/MADIS Data Distribution (3)



2.7 MDCRS

2.7.1 Concept of Operation

The Meteorological Data Collection and Reporting System (MDCRS) service collects and disseminates real-time upper-air weather observations from participating airlines. MDCRS is funded jointly by the U.S. government (FAA & NOAA NWS) and the seven participating airlines (American, Delta, Federal Express, Northwest, Southwest, United, and United Parcel Service), and operated by Aeronautical Radio, Inc. (ARINC). MDCRS is the United States' contribution to Aircraft Meteorological Data Reports (AMDAR), which is the generally-accepted worldwide term for automated weather reports from commercial aircraft. The data collected and disseminated through MDCRS are called Aircraft Communications Addressing and Reporting System (ACARS) data. ACARS is a proprietary system run by ARINC and is used by airlines to transmit a variety of proprietary air-to-ground communications with the seven airlines mentioned above also using ACARS to transmit meteorological data for MDCRS.

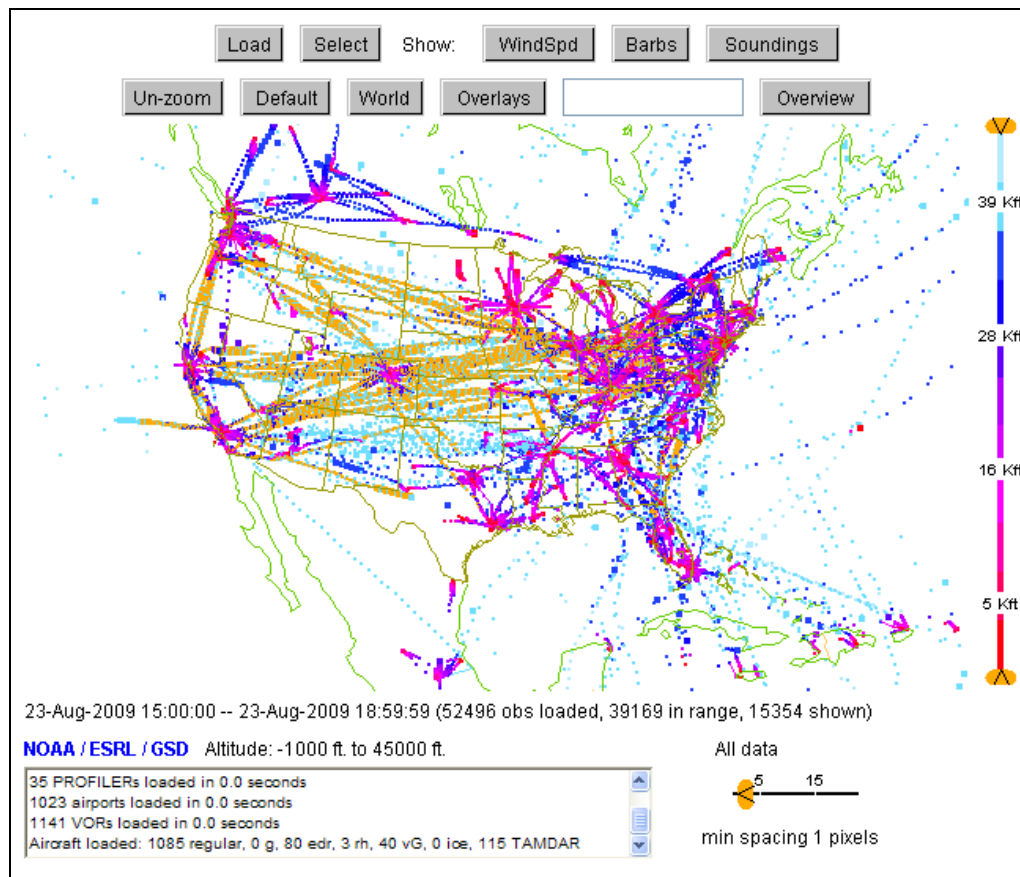
There are approximately 1,500 aircraft aircraft that report observations into MDCRS with total daily observations over the continental US numbering about 100,000. Onboard sensors report observations that get relayed through an air/ground VHF radio link along with other data communications. Data are then forwarded to ESRL/GSD where they are processed, quality controlled, and made available for access. However, since the ACARS data processed at GSD are proprietary to the airlines providing the data, the following guidelines have been developed regarding access. (In the statements below, "ACARS" refers to all aircraft data from GSD, including AMDAR data.)⁷

- Real-time ACARS data may be made available to those organizations that are performing research which, in the judgment of GSD, is likely to benefit the airlines providing the data.
- The data may not be redistributed in real-time. However, the use of images in research publications is allowed and encouraged.
- Researchers are encouraged to use ACARS data in Numerical Weather Prediction models. NWP model results may be made available to the public in real-time provided that all of the following conditions are met.
- Individual ACARS measurements may not be revealed (although gross numbers may be).
- ACARS must be one of several kinds of input observations (such as radiosondes and METARs).
- The model and data may not be used to develop products or services for sale.
- Real-time data are available to government agencies such as NOAA in support of forecasting operations.

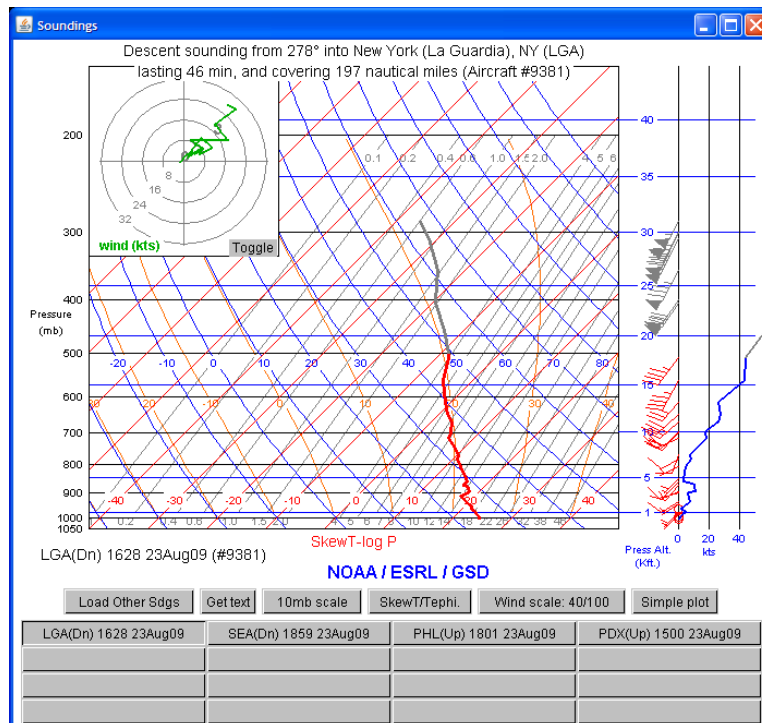
⁷ This information was taken from the AMDAR website (<http://amdar.noaa.gov/FAQ.html>)

- Real-time data may be made available only to those airlines that provide ACARS meteorological data to the US Government at their own expense. Data may not be shared with affiliate or code-share airlines.
- Real-time data may not be made available to commercial entities that would use them to develop products or services they plan to offer for sale to the participating airlines.

The following figure shows a demonstration display of AMDAR data using a Java applet on the GSD website:

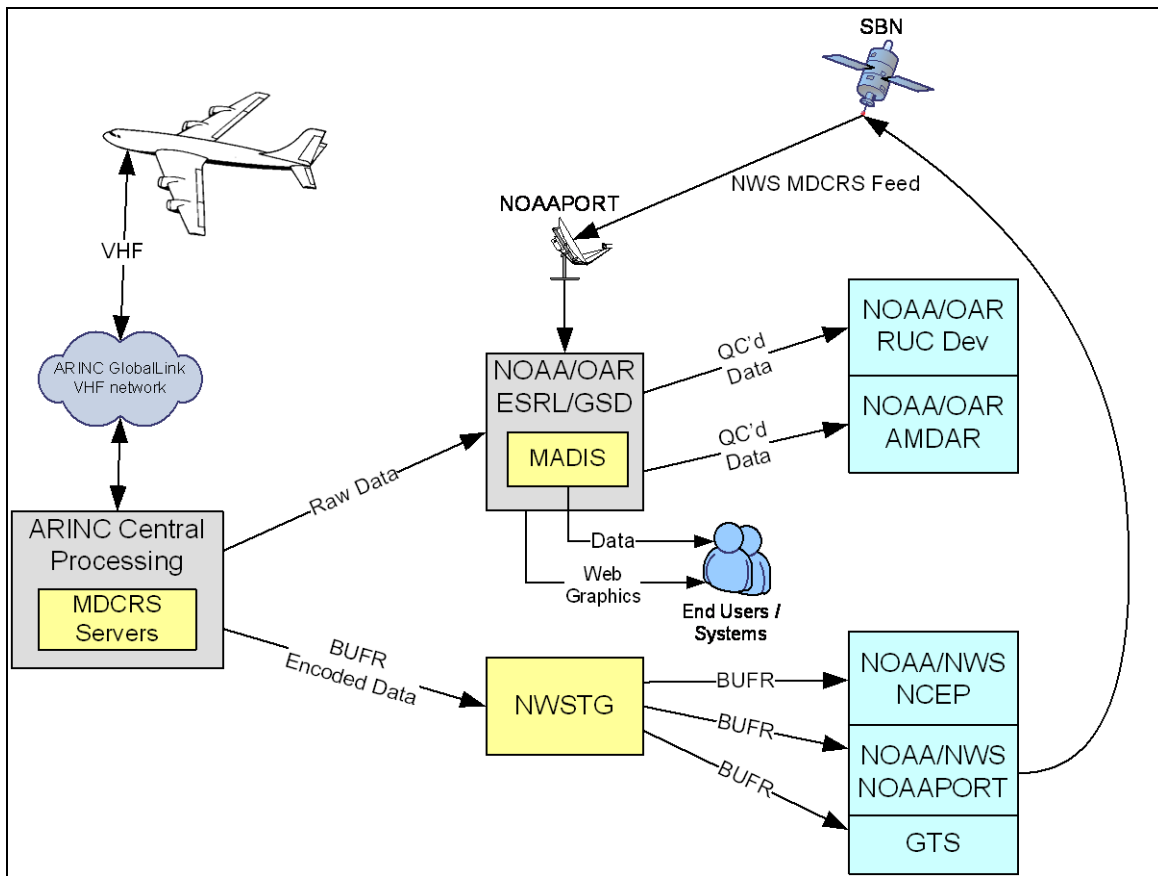


The following figure shows a sample popup display when a particular aircraft trajectory point is selected:



2.7.2 Technology Architecture / Information Flows

The MDCSR architecture is based on weather sensors and processing and communications equipment onboard aircraft, the supporting VHF radio network, ARINC's Central Processor and MDCRS server, NOAA's GSD and NWSTG, and the downstream consuming systems. The figure below shows a simplified depiction of the architecture:



The information flow represented in this block diagram starts with participating aircraft relaying observations via ARINC's GLOBALink VHF radio network to their central processing center. The MDCRS servers take the incoming data and remove message headers, extract raw weather data, validate formatting, remove airline and flight information, and encode the data in BUFR format. From here there are two paths to NOAA systems:

1. direct, raw data feed straight to ESRL/GSD (unprocessed, un-encoded data)
2. processed / BUFR encoded data to the NWS Telecommunications Gateway (NWSTG)

From the NWSTG, MDCRS data is forwarded to the National Centers for Environmental Prediction (NCEP), the NOAAPORT system, and the WMO Global Telecommunications System (GTS). NOAAPORT, through the NWS Satellite Broadcast Network (SBN), then serves as GSD's source feed for BUFR encoded MDCRS data. GSD decodes the BUFR data received from NOAAPORT and compares it with the raw data feed from ARINC. (GSD refers to "ACARS" data as those data decode here, and to MDCRS data as those data we receive from the NOAA GSD quality controls the raw data feed and removes duplicate data from the decoded data from NOAAPORT and assembles a data set that is forwarded for use in the RUC model and serves as the US contribution to the international AMDAR data set. This data, along with AMDAR and TAMDAR, are put into MADIS, which then serves as the consumer access point for end

users to access the MDCRS data itself. Graphical representations are accessed by users from the GSD website.

Approved users can access MDCSR/ACARS data in the following ways:

- Web-based graphical displays, either java-based or not
- Web-based access to binary data in netCDF format
- LDM access to binary data in netCDF format

MDCRS data are also made available through the following NWS dissemination systems: AWIPS, NOAAPORT, MADIS, LDAD, Family of Services (FOS), as well as through ARINC and the WMO Global Telecommunications System (GTS).

2.8 NCDC

2.8.1 Concept of Operation

The National Climatic Data Center (NCDC) is the world's largest active archive of weather data. Their mission is to provide access to and stewardship of the Nation's resource of global climate and weather related data and information, and assess and monitor climate variation and change. This effort requires the acquisition, quality control, processing, summarization, dissemination, and preservation of a vast array of climatological data generated by national and international meteorological services. NCDC's mission is global in nature and provides the U.S. climate representative to the World Meteorological Organization, the World Data Center System, and other international scientific programs. NCDC is also collocated with and operates the World Data Center (WDC) for Meteorology, which is one component of the World Data Center System that functions under the guidance of the International Council of Scientific Unions.

The Center has more than 150 years of data on hand with 224 gigabytes of new information added each day. NCDC archives 99 percent of all NOAA data, including over 320 million paper records; 2.5 million microfiche records; over 1.2 petabytes of digital data residing in a mass storage environment. NCDC has satellite weather images back to 1960. NCDC annually publishes over 1.2 million copies of climate publications that are sent to individual users and 33,000 subscribers. NCDC maintains over 500 digital data sets, receives almost 2,000,000 requests each year, and records over 100 million hits per year on the website.

The Center, which produces numerous climate publications and responds to requests from all over the world, provides historical perspectives on climate which are vital to studies on global climate change, the greenhouse effect, and other environmental issues. The Center stores information essential to industry, agriculture, science, agriculture, hydrology, transportation, recreation, and engineering.

The NCDC operates under NESDIS and has four divisions:

- Global Climate Applications Division

- Remote Sensing and Applications Division
- Climate Services and Monitoring Division
- Support Services Division

2.8.2 Technology Architecture / Information Flows

NCDC archives weather data obtained by the National Weather Service, Military Services, Federal Aviation Administration, and the Coast Guard, as well as data from voluntary cooperative observers.

These data received from a wide variety of sources include satellite, radar, remote sensing systems, NWS cooperative observers, aircraft, ships, radiosonde, wind profiler, rocketsonde, solar radiation networks, and NWS Forecast/Warnings/Analyses Products. NCDC supports many forms of data and information dissemination such as paper copies of original records, publications, atlases, computer printouts, microfiche, microfilm, movie loops, photographs, magnetic tape, floppy disks, CD-ROM, electronic mail, on-line dial-up, telephone, facsimile and personal visit. NCDC has increased data acquisition capabilities to ingest new data streams such as NEXRAD and ASOS.

NCDC operates the National Virtual Data System (NVDS), which is comprised of Climate Data Online (CDO) Services (e.g., Quality Controlled Local Climatological Data, etc.), GIS Services, an Image and Publications System, and NEXRAD Radar Data Services, among others areas. In FY2008, NCDC delivered over 338 Terabytes of online climate data, a 7 percent increase over FY 2007. This represents the continued growth of satellite, in-situ, NEXRAD, and model data. Over 1.8 petabytes of data are now accessible from NCDC's web site. To manage this increased data availability and demand for data, NCDC continues to implement new hardware upgrades to manage this growing online resource.

The high-level architecture of the NCDC is that of a basic data center with multiple ingest channels and methods and several electronic dissemination channels. The key dissemination methods are via HTTP transfer through web access and via FTP transfer. NCDC has also implemented Web Services access that currently supports observational data. The Web Services are planned to support access satellite and radar data in the medium to long term future.

NCDC offers numerous online data access tools for users to retrieve the many data and products available (<http://www.ncdc.noaa.gov/oa/dataaccessstools.html>). Many of the tools are GIS-based providing users with simple map-based access to climate services. Users who are presented with data discovery options which flow into detailed product selection maps can search using standard tools or gazetteer (geographical dictionary search) functions.

In addition to providing dynamic maps to access data, Web Map Services (WMS) provide maps or images and Web Feature Services (WFS) provide spatial features. These services may be used from Open Geospatial Consortium (OGC)-compliant applications to directly access data and metadata. KMZ files used directly within 3D GIS viewers (e.g., ArcExplorer, Google Earth) are also available for a number of datasets and products. Datasets and products are recorded in Federal Geographic Data Committee

(FGDC)-compliant metadata which are harvested into catalog portals such as Geospatial One-Stop (<http://gos2.geodata.gov/wps/portal/gos>) and the Global Change Master Directory (<http://gcmd.nasa.gov/>).

NCDC has also been producing and disseminating climatological publications for over 100 years. These include the following:

- The Local Climatological Data (LCD) publication is produced monthly and annually for some 270 cities. The LCD contains 3-hourly, daily, and monthly values. The annual issue contains the year in review plus normals, means and extremes.
- The Climatological Data (CD) publication, also produced monthly and annually, contains daily temperature and precipitation data for over 8,000 locations. The CD is published by state or region (New England), with a total of 45 issues produced each month.
- The Hourly Precipitation Data (HPD) is produced monthly. It contains data on nearly 3,000 hourly precipitation stations, and is published by state or region.
- The Storm Data (SD) publication documents significant U.S. storms and contains statistics on property damage and human injuries and deaths.
- The Monthly Climatic Data for the World (MCDW) provides monthly statistics for some 1,500 surface stations and approximately 800 upper air stations.

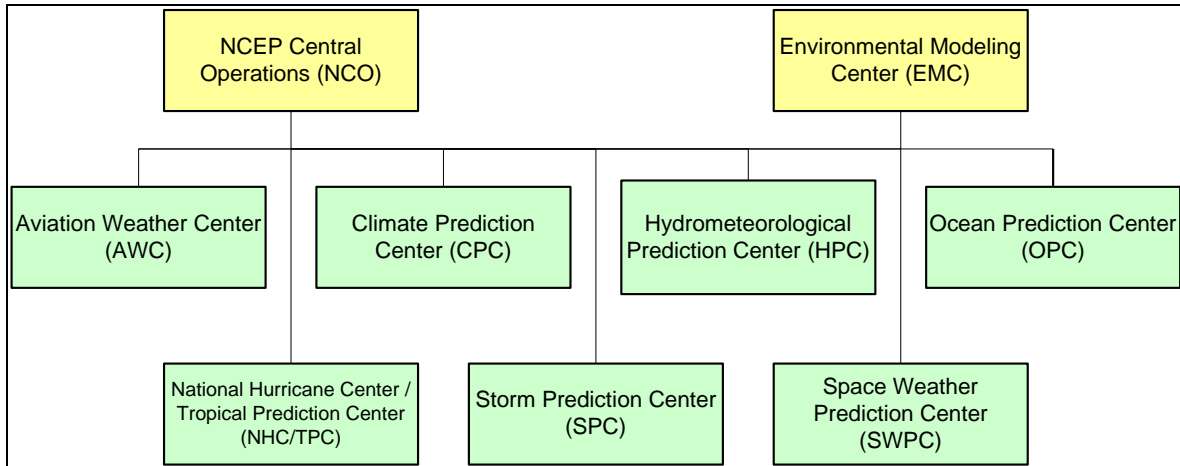
In addition to routine publications, NCDC also generates many non-periodicals including normals, probabilities, long-term station and state summaries, and several atlases covering the land areas, coastal zones, and oceans of the world.

2.9 NCEP

2.9.1 Concept of Operation

The National Centers for Environmental Prediction (NCEP) represents a critical national resource to operational and research communities affected by weather, water, climate, and space weather. NCEP provides primary support to the NWS mission by furnishing products designed to support NWS field operations, partners in the Private Sector, other government agencies, and the American Public.

NCEP consists of the centers represented in the figure below:



NCEP's Central Operations (NCO) and Environmental Modeling Center (EMC) infrastructure support the requirements of the broader user community, the specific needs of NCEP's seven Service Centers, and the NWS field forecast structure. The roles of the EMC and NCO are listed below:⁸

- The NCEP Central Operations (NCO) sustains and executes the operational suite of the numerical analyses and forecast model and prepares NCEP products for dissemination.
- The Environmental Modeling Center (EMC) develops and improves numerical weather, climate, hydrological and ocean prediction through a broad program of applied research in data analysis, modeling and product development in partnership with the broader research community.

The seven NCEP Service Centers rely on their experts to forecast specific weather phenomena. NCEP supports the field by staffing the Service Centers with highly trained forecasters focusing on hazards related to such areas as severe weather, tropical cyclones, heavy precipitation, marine and aviation weather, global climate, and space weather. This ensures that NWS field offices, other government agencies and the nation's private sector have the necessary information to deal with specific hazardous weather occurrences and extreme climate events, whenever and wherever they occur. The roles of the seven Service Centers are listed below:⁹

- The Aviation Weather Center (AWC) provides aviation warnings and forecasts of hazardous flight conditions at all levels within domestic and international air space.
- The Climate Prediction Center (CPC) serves the public by assessing and forecasting the impacts of short-term climate variability, and emphasizing enhanced risks of weather-related extreme events for use in mitigating losses and maximizing economic gains.

⁸ NCEP Strategic Plan 2009 - 2013

⁹ Ibid.

- The Hydrometeorological Prediction Center (HPC) provides analysis and forecast products, specializing in quantitative precipitation forecasts (QPF) to five days, weather forecast guidance to seven days, real-time weather model diagnostics discussions, and surface pressure and frontal analyses.
- The Ocean Prediction Center (OPC) issues weather warnings and forecasts out to five days, in graphical, text and voice formats for the Atlantic and Pacific Oceans, north of 30 degrees North.
- The Space Weather Prediction Center (SWPC) provides space weather alerts and warnings for disturbances that can affect people and equipment working in space and on Earth.
- The Storm Prediction Center (SPC) provides accurate tornado and severe weather forecasts and watches for the contiguous United States along with a suite of hazardous weather and mesoscale products. The SPC continually monitors mesoscale atmospheric processes related to severe weather and tornado outbreaks, extreme winter weather events and critical fire weather conditions.
- The National Hurricane Center (NHC) (Tropical Predictions Center (TPC)) provides official NWS forecasts of the movement and strength of tropical weather systems and issues the appropriate watches and warning for the U.S. and surrounding areas. The NHC also issues a suite of marine products covering the tropical Atlantic and eastern Pacific.

A few key models that are a part of the NCEP operational suite are the Global Forecast System (GFS), High Resolution Rapid Refresh (HRRR), Localized Aviation MOS Program (LAMP), North American Mesoscale Visible / Infrared (NAM V/R), and the Rapid Update Cycle (RUC). Many of these models serve as inputs to FAA systems to produce aviation specific products.

Global Forecast System (GFS)

The GFS is a global spectral data assimilation and forecast model system. GFS forecasts are produced every six hours 00, 06, 12 and 18 UTC. The GFS graphics are based on 70km grid and are available at six hour increments out to 384 hours. The GFS also produces 35 km forecasts out to 180 hours but these are not converted to graphic images. The current horizontal resolution is approximately 35km in both analysis and forecast models. The vertical resolution is at 64 layers.

High Resolution Rapid Refresh (HRRR)

The HRRR is a 3km resolution, hourly updated, cloud-resolving atmospheric model. The model is initialized with the latest 3-D reflectivity via 13km RUC. The model will provide improved background fields for NWS real-time Mesoscale Analysis, and improved basis for other aviation hazard forecasts (i.e – wake vortex, ceiling and visibility, turbulence, icing, terminal forecasts).

North American Mesoscale (NAM)

The NAM model is a regional mesoscale data assimilation and forecast model system based on the WRF common modeling infrastructure, currently running at 12 km resolution and 60 layers. NAM forecasts are produced every six hours at 00, 06, 12, and 18 UTC.

Rapid Update Cycle (RUC)

The RUC is a hybrid sigma-isentropic analysis and forecast system. It has a horizontal resolution of 13 km and 50 vertical layers. RUC utilizes an hourly data assimilation system. The RUC forecasts are produced every hour.

2.9.2 Technology Architecture / Information Flows

All the products that are from the nine centers are a part of the NCEP operational model suite, or the NCEP model suite. The NCO executes the NCEP model suite, manages improvements to the NCEP model suite, develops meteorological software, and manages the flow of data and products. The NWSTG acts as the front-end to NCEP for general NWS consumption by communicating directly with the NCO.

Some of the data and products available from NCEP are restricted for use by users within the NCEP CCS community. These restrictions are required by the data providers and NCEP honors these restrictions as the data are passed through NCEP systems and use in models and other data presentations. Likewise, quality-controlled data values that are directly derived from restricted data are themselves also subject to the same restriction(s) as the original data.

Standards supported by NCEP / NCO include the following:¹⁰

- NCEP adheres to WMO standards
 - GRIB, BUFR, CREX formats are primary
- NetCDF is supported as well, however on a limited basis
- Fortran is predominant language on Central Computer System (CCS)
 - C, C++, Java, Python are also all used and supported by NCO

NCEP can support just about any standard and is willing to add capabilities within the NCO for additional standards and services. However, any community or office approaching NCEP with a request for additional capabilities must have a strong, solid business case and must have continued backing of the development organization.

¹⁰ *NCEP Central Operations Capabilities* presentation; Brent Gordon, NCEP/NCO/Systems Integration Branch; NOAA System of Systems Workshop, October 7, 2009.

2.10 NDFD

2.10.1 Concept of Operation

The NOAA NWS National Digital Forecast Database (NDFD) contains gridded forecast weather information stored on public and restricted access servers called the NDFD Central Server System (CSS). The NDFD provides a seamless mosaic of digital forecasts from NOAA NWS field offices (WFOs) working in collaboration with the National Centers for Environmental Prediction (NCEP). The NDFD is designed to provide access to weather forecasts in digital form from a central location with data being updated hourly, usually at 45 minutes after the hour. The NDFD also performs forecast verification on a number of forecast products and makes the resulting verification scores available to users. Digital forecast data are archived for all NWS Weather Forecast Offices (WFO's) and are mosaiced and available for access for the contiguous United States (CONUS), Alaska, Hawaii, and Guam, as well as 16 predefined subsectors covering the CONUS. The NDFD will eventually also contain watch and warning information and weather elements from NCEP centers, such as marine and climate products.

The database is made available to all customers and partners from the public, private, and academic sectors. Those customers and partners may use this data to create a wide range of text, graphic, gridded and image products of their own.

The existing CSS is used operationally to support the dissemination of official and experimental digital products and is considered to be a part of the operational AWIPS baseline hardware under formal operations and maintenance. The project sponsor and requirement owner is the Office of Climate, Water, and Weather Services (OCWWS). The Office of Science and Technology (OS&T) is the organization responsible for development, operation, and maintenance of the CSS hardware. The maintenance of the hardware is a responsibility of the System Engineering Center (SEC) and the software maintenance is a responsibility of the Meteorological Development Laboratory (MDL). The Office of the Chief Information Officer (OCIO) is responsible for dissemination of the digital data processed on the CSS.

2.10.2 Technology Architecture / Information Flows

Data are prepared for and input to the NDFD through the following processes involving the WFOs, NCEP, and the resources at the NDFD CSS.

Input Creation / Collaboration

The NDFD provides access to official NWS forecasts produced by forecasters at local weather offices and national centers. Collaboration in the creation of the NDFD data is carried out at three levels—among NCEP and WFOs, between adjacent WFOs, and a final quality control check at the NDFD central server and by NCEP.

NCEP–WFO collaboration. NCEP issues digital guidance targeted for the affected areas. While the WFOs have responsibility for the production and accuracy of their gridded products for their areas, NCEP plays a role in the longer time ranges forecasts.

WFO–WFO collaboration. WFOs produce their grids via IFPS. Subsets of these grids are sent to the neighboring WFOs; while software allows simultaneous viewing of grids from both WFOs and provides chat capability to facilitate boundary consistency.

Central quality control. When the forecast grids from the WFOs arrive at the NDFD CSS, they are automatically checked for consistency at the boundaries by software. If a discontinuity greater than the agreed upon threshold is detected, the submitting WFOs are automatically notified of a potential problem. NCEP also has the opportunity to view the mosaic and offer suggestions to the WFOs.

Importing into NDFD

The Interactive Forecast Preparation System (IFPS) is a software suite that NWS meteorologists use to prepare their forecasts, storing meteorological fields in the NDFD. IFPS provides not only for preparation of familiar text based products, but also creates in digital (i.e. numerical) form a database from which a wide range of new graphical and digital forecast products can be generated.

Meteorologists at each National Weather Service office first import digital computer model and sensible weather data into a Graphical Forecast Editor (GFE). Then, using advanced tools and techniques within the GFE, the forecaster interactively manipulates the digital data for each forecast element or grid. Each point on a grid represents a separate place and time in the forecast period. Using the GFE, meteorologists assign a value to every grid point for each different weather element, and for each time in the forecast period. When the grid editing is completed, the weather element grids are stored and transmitted to the NDFD.

Access to the NDFD's CSS is provided via the internet, FOS, and NWSTG FTP.

NDFD products are available in the following formats:

- Grids in Gridded Binary (GRIB2) format
- Element data
- Graphics

GRIB2 data is available through:

- Anonymous FTP
- Server Access Service of the Family of Services
- HTTP over the Internet

NDFD Elements are available through:

- Web Feature Services (WFS) – OGC standard; GML; dwGML
- XML web service – SOAP, DWML
- REST service – DWML

The CSS consists of three dual-server clusters:

- Two redundant clusters are located at AWIPS NCF.
- One cluster at AWIPS backup NCF.

Two inputs of data to NDFD CSS:

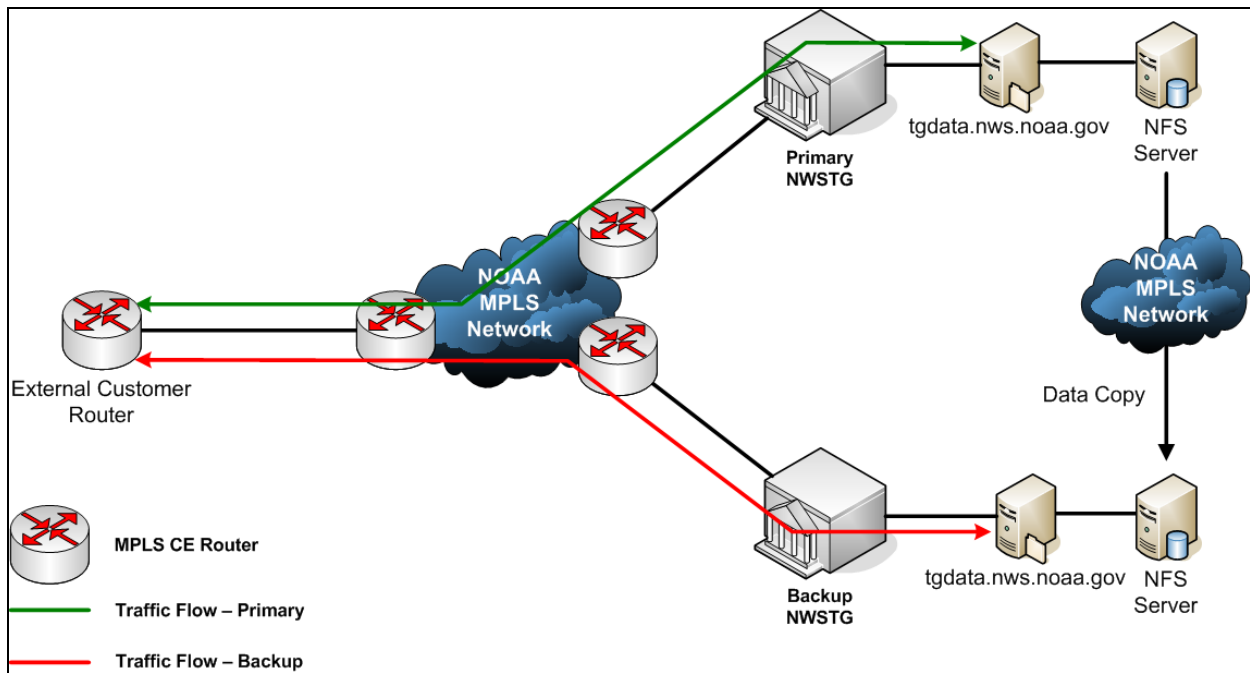
- WFOs – IFPS Service Backup netCDF files via SvcBu rsync servers.
- NCEP – GRIB2 from TPC, SPC, CPC, and EMC; text from HPC

Three outputs of data from NDFD CSS:

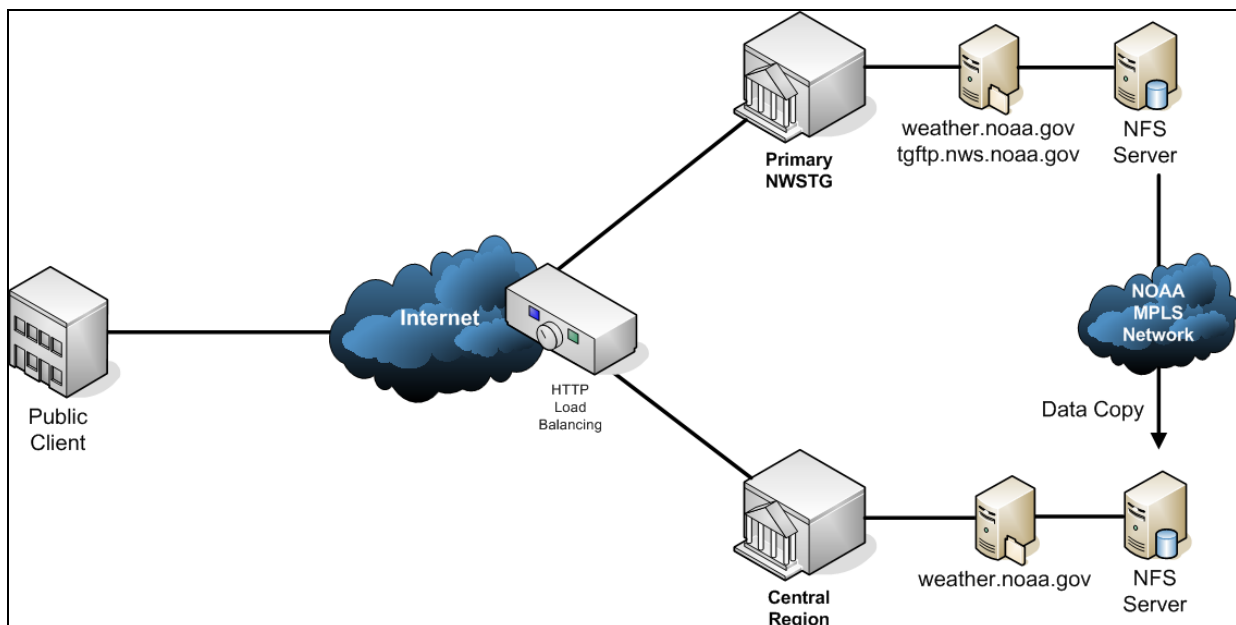
- TOC – GRIB2, XML.
- NWS Web Farm – GRIB2
- RFC (pulled via AWIPS WAN) – GRIB2

The figure below depicts the basic architecture and access approach for those external customers with dedicated communications to the NDFD network file system (NFS) server.¹¹ These connections are through the NOAA net MPLS network using appropriate customer provided and NWS provided routers. Data requests and associated data responses flow through the NWSTG from the NFS servers and is configured with a primary servers at the NWSTG in Silver Spring, MD, and backup servers at the Backup NWSTG for non-public service and at the Central Region Headquarters for public internet service.

¹¹ Drawings in this section were taken from a presentation given by Allan Darling in November 2006.



The figure below depicts the basic architecture and access approach for those external customers with internet-based communications to the NDFD NFS server.



2.11 NDGD

2.11.1 Concept of Operation

The National Digital Guidance Database (NDGD) is a sister to the National Digital Forecast Database (NDFD). Information in NDGD may be used by NWS forecasters as guidance in preparing official NWS forecasts in NDFD.

NDGD contains forecasts and observations of sensible weather elements that relate to and supplement NDFD. It will also contain digital data that help in the use and interpretation of NDFD, such as model probabilities, climatological normals, and NDFD verification scores.

NDFD is always current. It is intended to provide a complete and consistent forecast in time and space, among elements, and with other official NWS forecast products. In contrast, NDGD is updated on a schedule from a variety of model sources. It is not necessarily consistent with other parts of NDGD or with official NWS forecast products.

2.11.2 Technology Architecture / Information Flows

NDGD elements are derived from the following sources:

- Gridded Model Output Statistics (MOS) – Downscales MOS to a fine resolution grid with skill comparable to station-oriented guidance
- Air Quality
- Local Aviation MOS Program (LAMP) - Updates Station MOS guidance for 25 hours in 1 hr increments
- Sea, Lake, and Overland Surge from Hurricanes (SLOSH)
- Real Time Mesoscale Analysis (RTMA)
- Ensemble Kernel Density MOS – Provides reliable probabilistic forecast of temperature, dew point, daytime temp max, nighttime temp min

NDGD products are available in the following formats:

- Grids in Gridded Binary (GRIB2) format
- (Note : However, some data is also available directly from source models, or available graphical from the Internet)

NDGD products can be obtained via the following methods.

Grid based products are available via

- Anonymous FTP
- Server Access Service of the Family of Services.
- HTTP over the Internet

2.12 NESDIS

2.12.1 Concept of Operation

NOAA's National Environmental Satellite, Data, and Information Services (NESDIS) operate the United States geostationary and polar-orbiting environmental satellites. The geostationary satellites are complimentary and essential to monitoring daily weather and longer term climate changes. They are located at longitudes optimized for maximum coverage of the United States and nearby areas. The satellites provide constant coverage of the western hemisphere by taking photographic images every 15 minutes. The Geostationary Operational Environmental Satellites (GOES) imagery is critical to forecasting the location of weather phenomena. In addition to basic imagery, on-board sensors detect cloud, land, and ocean temperatures, as well as monitor activities of the sun. NOAA GOES are also used in identifying when satellite emergency locator beacons have been activated to help with Search and Rescue activities.

In addition to GOES, there are two Polar-Orbiting Environmental Satellites (POES) that measure, among other things, atmospheric wind and temperature conditions and global ocean temperatures for input into daily computer weather forecast models and longer term climate studies. Data from the POES series supports a broad range of environmental monitoring applications including weather analysis and forecasting, climate research and prediction, global sea surface temperature measurements, atmospheric soundings of temperature and humidity, ocean dynamics research, volcanic eruption monitoring, forest fire detection, global vegetation analysis, search and rescue, and many other applications.

NESDIS is composed of the following organizational components:

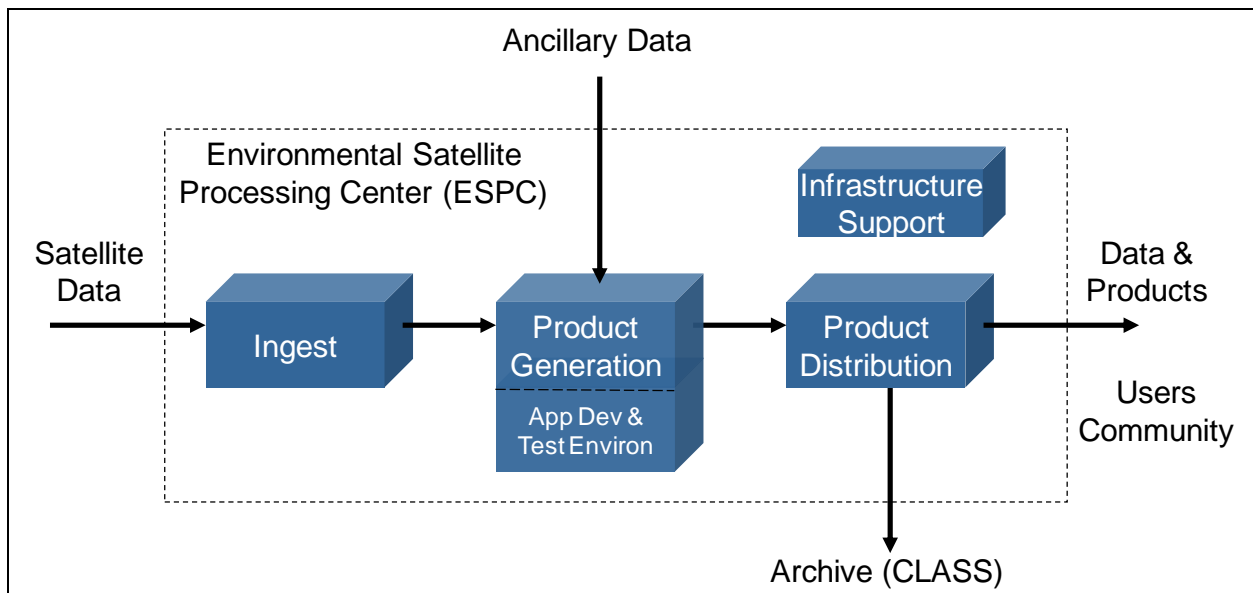
- National Climatic Data Center
- National Geophysical Data Center
- National Oceanographic Data Center
- National Coastal Data Development Center
- Office of Systems Development
- Office of Satellite Operations
- Office of Satellite Data Processing & Distribution
- STAR - Center for Satellite Applications and Research
- NPOESS Integrated Program Office
- GOES-R Program Office
- International & Interagency Affairs Office
- Office of Space Commercialization

- Commercial Remote Sensing Compliance and Monitoring Program

Through these data centers and other centers of data, NESDIS provides and ensures timely access to global environmental data from satellites and other sources, provides information services, and develops science products.

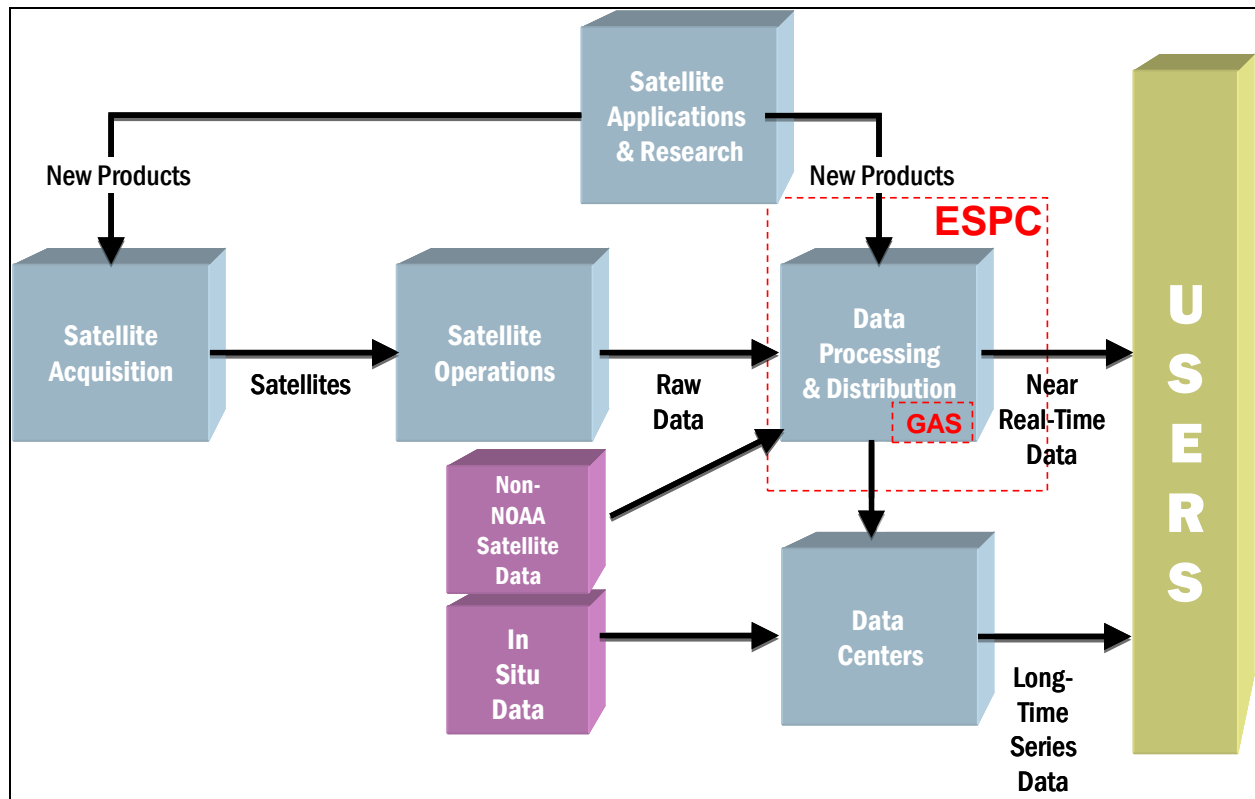
2.12.2 Technology Architecture / Information Flows

The Environmental Satellite Processing Center (ESPC) is the consolidation of separate GOES and POES satellite data processing centers. The ESPC is located at the National Satellite Operations Facility (NSOF) in Suitland, MD, with a backup ground system at Wallops Island. ESPC operates the telecommunications systems that receive satellite signals from GOES/POES satellites, and the computational systems that process the satellite data into a set of several hundred environmental information products that are routinely distributed to the NWS, DoD, FAA, and other users. The basic information flow is depicted in the figure below:¹²



One important component is the GOES Access Subsystem (GAS), which is a subsystem of the GOES-R Ground Segment system responsible for receiving and storing GOES-R data and products in 7-day temporary storage and making them available to authorized users. GAS is being developed and integrated as a part of an enterprise NESDIS Data Processing and Distribution operational capability; i.e., as a part of the NESDIS ESPC. The basic functional architecture of NESDIS including GAS is shown in the figure below:

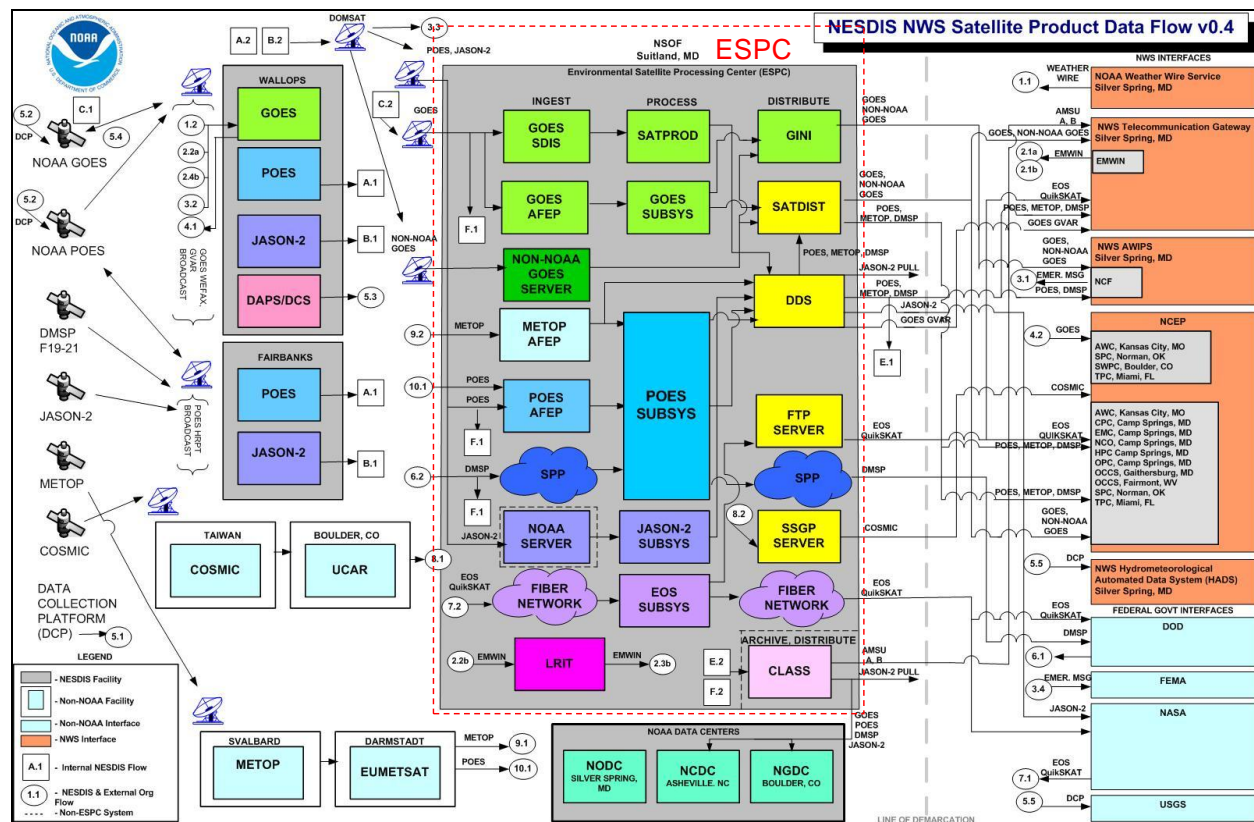
¹² Figures in this section on NESDIS were taken from the *Environmental Satellite Product and Distribution System (ESPDS) GOES-R Access Subsystem (GAS)* presentation; John Linn, ESPDS Systems Engineering; NOAA System of Systems Workshop, October 7, 2009.



Supported data formats include:

- Man-computer Interactive Data Access System (McIDAS)
- Network Common Data Format (NetCDF)
- Flexible Image Transport System (FITS)

The overall NESDIS satellite system baseline data flow is shown in the following figure:



2.13 Verification Systems

A number of systems are in place, or are under development, to serve the purpose of verifying NWS forecast products, particularly those related to aviation. This section summarizes the four primary verification systems of interest to aviation and subsequently to the Cube.

2.13.1 Real-Time Verification System¹³

Over the past several years, the FAA Aviation Weather Research Program (AWRP) has funded the NOAA's ESRL (formerly Forecast Systems Laboratory) to develop the Real-Time Verification System (RTVS). This system, currently operated at ESRL, provides statistics for operational aviation forecast products being created by the Aviation Weather Center (AWC) and the Alaska Aviation Weather Unit (AAWU). It also generates statistics for experimental products that are being introduced to the National Weather Service (NWS) through the Aviation Weather Technology Transfer (AWTT) process.

The RTVS, currently running at ESRL, provides verification statistics and displays for a variety of forecast and diagnostic products. These products and the observational data to which they are compared are ingested into the system as soon as they become available from the operational data feeds. Processing,

¹³ This section is taken from the *preliminary draft* of the NEVS OSIP 09-011 *Concept of Operations and Operational Requirements*. Section needs to be revisited upon final release of NEVS OSIP documentation.

specifically designed for each meteorological product, creates appropriately stratified forecast and observation pairs that are stored in a relational database. A Web interface allows a user to create customized output in either graphical or tabular form for a number of standard verification measures. The latest version of the RTVS page and Convective Display interface can be accessed at the following URL: <http://www-ad.fsl.noaa.gov/fvb/rtvs/index.html>

The RTVS is an automated stand alone system lacking backup capabilities and without interfaces to other NWS verification systems or AWIPS.

RTVS provides tools for four aviation services verification areas: the Convective Statistical Tools, the Ceiling and Visibility Statistical Tools, the Icing Statistical Tools, and the Turbulence Statistical Tools. A statistical record of the accuracy of national scale forecasts back to 1998 is available in RTVS.

In addition to use for real-time verification, RTVS is also used for decision-making to assess the readiness for transition of experimental products from research to FAA and NWS operations. Examples of products evaluated using RTVS are the National Convective Weather Forecast Product versions 1 and 2, and the Collaborative Convective Forecast Product. Publications describing the results of these forecast product evaluations are available from: <http://www-ad.fsl.noaa.gov/fvb/publications>

RTVS provides verification capabilities for official NWS forecasts, and capabilities for comparison of these forecasts to numerical and statistical guidance products. The system has been designed to meet the needs of operational forecasters for real-time feedback, however there are known limitations to its effectiveness for aviation product quality assessment.

One of the known limitations of RTVS relates to the operational decision-making by ATM and aircraft to re-route flights around areas where warning conditions are forecast, since FAA flight orders prohibit flying into warned areas. Aircraft are therefore not traversing through forecast areas of high impact weather (i.e., severe turbulence). This therefore limits the number of pilot reports (PIREPS) available for the geographic areas with the forecast warning conditions that can be used as verification sources for these issued warnings. The present design of RTVS relies upon the availability of PIREPS for verification of these warning conditions.

Another limitation of the existing RTVS is that the system is not modular and adaptive and is not able to integrate non-meteorological data for evaluation.

2.13.2 Stats on Demand (SOD) ¹⁴

The NWS Performance Branch Stats on Demand (SOD) program is the official NWS Terminal Aerodrome Forecast (TAF) verification tool and is utilized for all terminals for which the NWS issues TAFs. In the SOD system, TAFs are evaluated twelve times per hour at the end of every 5-minute interval. Forecast conditions at the end of each 5-minute interval are matched with the most recent observations reported in METARs and SPECIs, and each element (i.e., ceiling, visibility, wind, significant weather type) is verified

¹⁴ This section is taken from the *preliminary draft* of the NEVS OSIP 09-011 *Concept of Operations and Operational Requirements*. Section needs to be revisited upon final release of NEVS OSIP documentation.

separately. The ceiling and visibility elements are combined into a quantity called flight category, which is important to aviation operations and is verified separately.

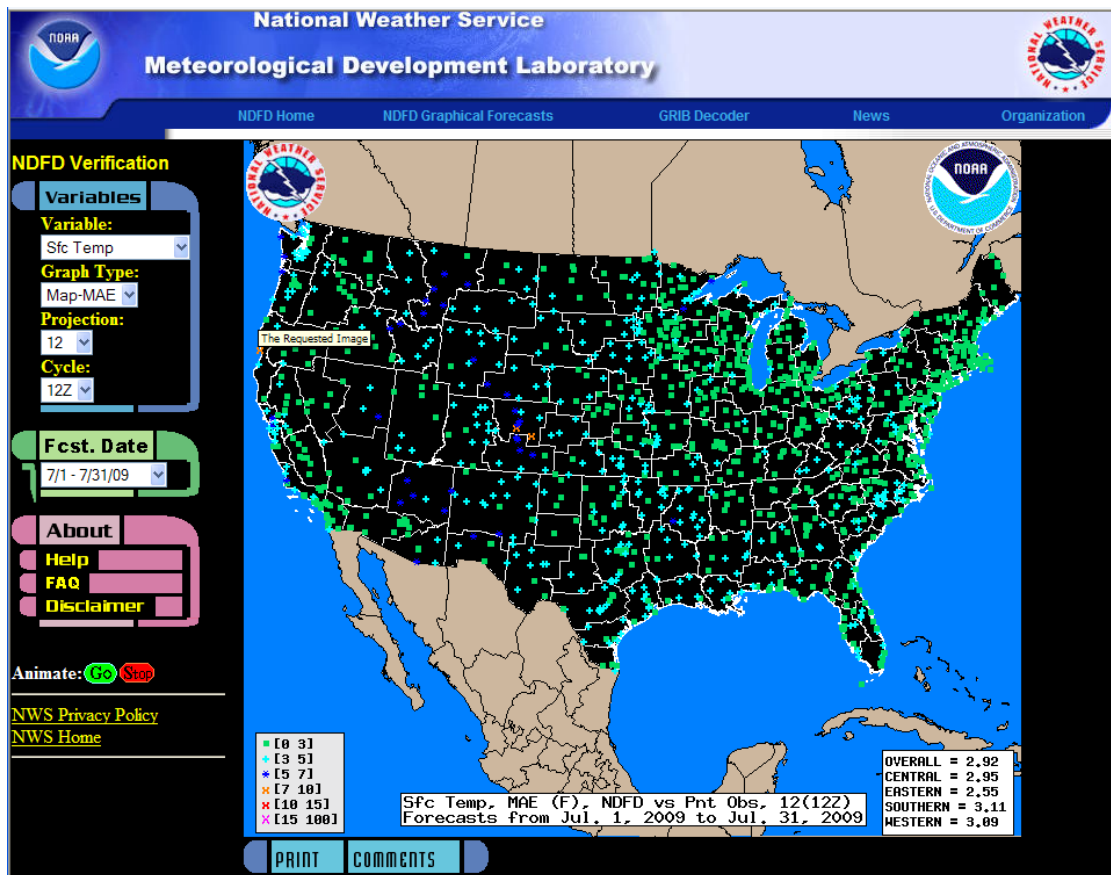
The following types of forecasts in the TAF are tracked, and data are available upon request: (1) prevailing forecast (the weather conditions in the first line of the TAF and associated with PM change groups), (2) TEMPO (temporary) forecasts, and (3) PROB (probabilistic) forecasts. A fourth "type", called the operational Impact forecast, is not a true forecast but an algorithm that looks at (1), (2), and (3) and selects the forecast most likely to impact aviation operations. TEMPO forecasts imply variability in conditions so TEMPO verification is highly dependent upon a variability test. The operational impact forecast is also highly dependent upon variability whenever a TEMPO forecast is used.

The latest Performance Branch Aviation Verification Page and SOD interface can be accessed at the following URL: <https://verification.nws.noaa.gov/content/pm/verif/aviation/index.aspx>

2.13.3 NDFD Verification

The following figure is a screen capture from the NDFD web-based verification statistics system.

Additional details will be provided in a subsequent update of this document.



2.13.4 NEVS

2.13.4.1 *Concept of Operation*

The Network-Enabled Verification Service (NEVS) is a system under development that will provide verification capabilities for all operational and selected experimental NWS Aviation Services products issued from forecast offices and national centers with aviation responsibility. NEVS will be used in real-time by the FAA and NWS for verification information, as a formal verification archive of official product accuracy, and for retrospective evaluations of forecasts. NEVS is being developed by NOAA's Earth Systems Research Laboratory (ESRL) Global Systems Division (GSD) by applying NextGen engineering strategies and concepts and user-specific verification techniques for providing automated real-time verification information to the 4-D Weather Cube and the SAS.

ESRL has developed and tested the initial version of NEVS as a proof-of-concept that provides end-to-end capability, and integrates information on-the-fly. It is intended to support real-time evaluation of CoSPA and other convective algorithms starting in 2009. The full transition of NEVS will occur in several phases with an initial operating capability being deployed in 2012. New verification techniques, assessment strategies, and engineered components will be integrated into NEVS over the following five to eight years. Due to the limitations of RTVS and the determination that it is not cost-effective to fully transition and implement the RTVS into NWS operations, NEVS will serve to replace RTVS upon transition to operations. NEVS will include all functions of the RTVS and is planned to fulfill NextGen verification requirements in support of IOC. Leading up to initial operations, NEVS will be operated in parallel with RTVS until it can be validated that NEVS successfully performs all functions currently contained within RTVS.

NEVS is intended to provide assessment of the performance of forecasts in the SAS and will be used in real-time by the FAA and NWS for verification information, as a formal verification archive of official product accuracy, and for retrospective evaluations of forecasts. The flexible framework upon which NEVS is built allows verification information created by any components of the Cube to be published and integrated into one service, enabling NEVS to act as the SAS of verification. Critical to this role is the ability to integrate non-meteorological information provided by other services within the software architecture. NEVS contains a wide array of verification approaches and metrics. Beyond the standard dichotomous and probabilistic measures, it provides object-based analysis, computation of non-parametric confidence intervals on statistics, and evaluation of forecasts on air traffic sector grids. The emphasis of NEVS is on collaborative data integration, forecast comparison, detailed statistical analysis, and network-enabled dissemination of specific verification information to a variety of end users. NEVS takes advantage of relational database management systems and web-based technologies for access to, and dissemination of, statistical information. The NEVS framework will help to unify resources from various organizations, will allow for data sharing and rapid transition of verification information to automated decision support tools and human forecast processes, and will ultimately provide a more complete assessment of forecast quality for user-specific applications. NEVS will generate statistical metrics that are stratified for operational meaningfulness (i.e., strategic planning periods, weather

traffic impact (WITI), and effective valid time). Traditional grid to grid verification approaches and the newly developed sector approach are also introduced within NEVS.

Target capabilities of NEVS include the following:¹⁵

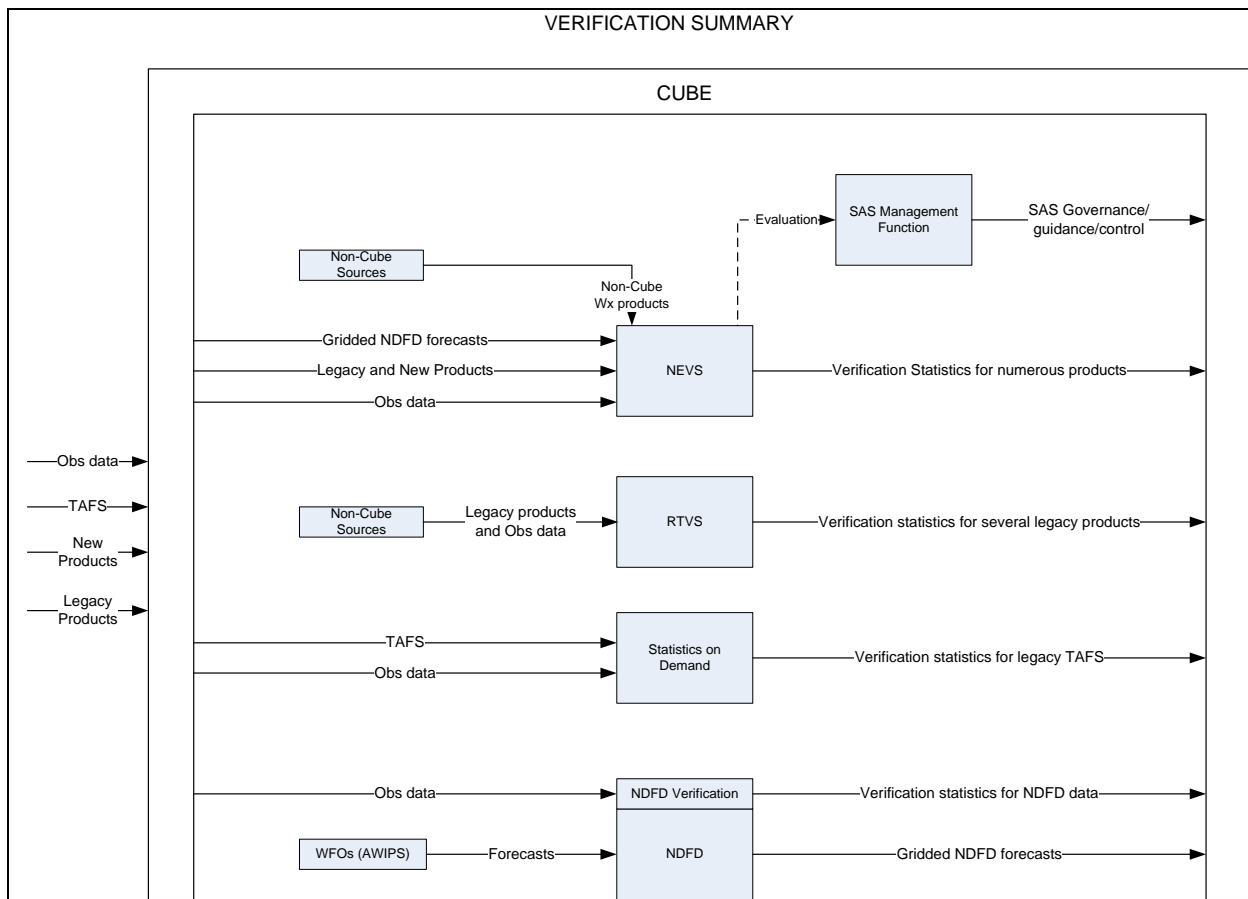
- Automated verification and assessment information for the 4-D Weather Cube: NEVS will provide real-time user-specific information to accompany the weather data that will reside within the WIDB and the SAS.
- User-specific verification techniques: NEVS will provide user-specific verification and evaluation techniques that form the foundation for improving weather information to end users. New techniques will be developed as required in order to properly assess and improve the quality of weather forecasts in the context of their use.
- Verification record of operational aviation products: NEVS will provide ongoing, long-term verification measures of all operational aviation products. Information, both forecasts and associated observations, must be ingested from established operational data feeds. The statistics must be computed and stored in a timely, efficient manner. This long-term record, consisting of all relevant verification measures, must be available via a web interface and network-enabled technologies that allow users to effectively interrogate the entire statistical dataset. The system must be able to import and manage the existing set of verification information, which dates back to 1999.
- Feedback of verification information to forecasters: NEVS will provide near real-time information via a web interface and network-enabled technologies to forecasters in the field. Information will include such items as statistical plots and displays that effectively depict the quality of the most recent forecasts. The information must be accessible in a timely manner to support the next forecast cycle for a given product.
- Support for operational certification of new aviation products: NEVS infrastructure will be adaptable to support verification of new forecast products as they transition into operations from research and development platforms. In addition to any existing data management and statistics processing, the system needs to effectively incorporate the necessary computational capability for any required newly developed verification approaches.
- Operationally robust performance: NEVS will provide a continuous data record and automated real-time input to the WIDB. Procedures and tools must exist to effectively recover from system failure or data dropout. The web interface and direct data access must be available at a level commensurate with user needs. The infrastructure of the verification service must comply with NextGen network-enabled technologies and formats.

¹⁵ Taken from NEVS OSIP Project #09-011 Statement of Need

- Quality Management System (QMS) compliance: NEVS must meet the requirements of the International Civil Aviation Organization (ICAO) mandated QMS managed by the FAA. Basic requirements are: a verification program that reflects production quality evaluation, product forecast verification, and ability to receive user feedback on the product usability or applicability to the weather actually encountered.

2.13.4.2 Technology Architecture / Information Flows

The anticipated high-level architecture of the subject verification systems in relation to the Cube is depicted in the figure below.



NEVS will collect various gridded forecasts, legacy and new aviation weather products, and observational data from both the Cube and non-Cube sources. The system will then perform the required verification on a product-by-product basis and make verification statistics for each available. Verification statistics will be available directly from the system and will also be sent back into the Cube. For direct access, NEVS will provide a Web-based interface for the human facing element of the verification process. It is expected that a similar interface would be available to users of the Cube as well as appropriate machine-to-machine interfaces. NEVS will also forward evaluation data to the SAS management function, where this data is envisioned to be used by NOAA and the FAA for justification to support the determination of the data contents provided in the SAS.

RTVS will continue to operate collecting legacy forecast products and observations, performing verification, and outputting verification statistics until such time that NEVS is considered operational with all of the functionality of RTVS. If this is not accomplished by Cube IOC, then the verification statistics from RTVS may need to be formatted and ingested into the Cube for some period of time. Otherwise, if NEVS is operational at IOC as planned, RTVS will likely not contribute data into the Cube.

Stats on Demand will continue to collect TAFs and relevant observational data, perform verification, and output verification statistics. As it is not currently foreseen that NEVS will implement a TAF verification function, SOD will continue as the TAF verification system and will need to have its output formatted accordingly for ingest into the Cube.

NDFD will also continue forecast and data collection, verification, and output of verification statistics, as well as output of its primary gridded forecast data. Both the NDFD forecasts and the associated verification statistics will be formatted accordingly and made available to the Cube.

Each of these systems that will continue operations in a state that supports interaction with the Cube is expected to support both ad hoc and subscription data transfers. The verification systems will be able to make ad hoc forecast and observational data requests from the Cube as well as setup subscriptions to those data. Downstream, these systems should support ad hoc and subscription distribution of their verification statistic data sets to various users through the Cube.

To achieve the state in these verification systems contribute into the Cube, standard formatting will need to be established for the respective verification statistics outputs.

2.14 NOMADS

2.14.1 Concept of Operation

NOAA Operational Model Archive and Distribution System (NOMADS) is a network of data servers using established and emerging technologies to access and integrate model and other data stored in geographically distributed repositories in heterogeneous formats. NOMADS enables the sharing and comparison of model results and is a major collaborative effort spanning multiple Government agencies and academic institutions. The data available under the NOMADS framework include model input and Numerical Weather Prediction (NWP) gridded output from NCEP, and Global Climate Models (GCM) and simulations from GFDL and other leading institutions from around the world. The goals of NOMADS are to:

- Improve access to NWP and GCM's model output and provide the observational and model data assimilation products for Regional model initialization and forecast verification.
- Promote improvements to operational weather forecasts.
- Develop linkages between the research and operational modeling communities and foster collaboration between the climate and weather modeling communities.

- Promote product development and collaboration within the geo-science communities (ocean, weather, and climate) to study multiple earth systems using collections of distributed data under sustainable system architecture.

2.14.2 Technology Architecture / Information Flows

At present NOMADS provides real-time and historical access to:

- Numerical Weather Prediction (NWP) model input and output
- GFDL's Coupled Global Climate Models (CGCM) output
- Global and regional reanalysis from NCEP and the National Center for Atmospheric Research (NCAR).
- Limited surface, upper-air and satellite observational datasets from NCDC, NOAA's National Ocean Data Center (NODC), and NOAA's Forecast System Laboratory (FSL).

NOMADS participants serve their data sets through a client-server relationship, that is, the data sets are Internet-ready and the display is done by the user, or client. The NOMADS approach to data distribution is applicable to a large set of data products, including both observational and numerical model-based files, and can serve users interested in time scales ranging from those associated with synoptic weather features to those related to decadal to centennial climate issues.

NOMADS operates on high availability distribution servers at two different locations using the same protocol to distribute model data. The real time data service is on a high availability server at the NOAA Web Operations Center (WOC) and archives of model and other data are hosted from NCDC. The NOMADS servers ingest model and ensemble data from the NCEP Central Operations (NCO), which is committed to the information flow aspect of NOMADS for data to be present and on time from their Operational super computers. NOMADS participants serve data sets through the client-server relationship including machine and man readable metadata descriptions.

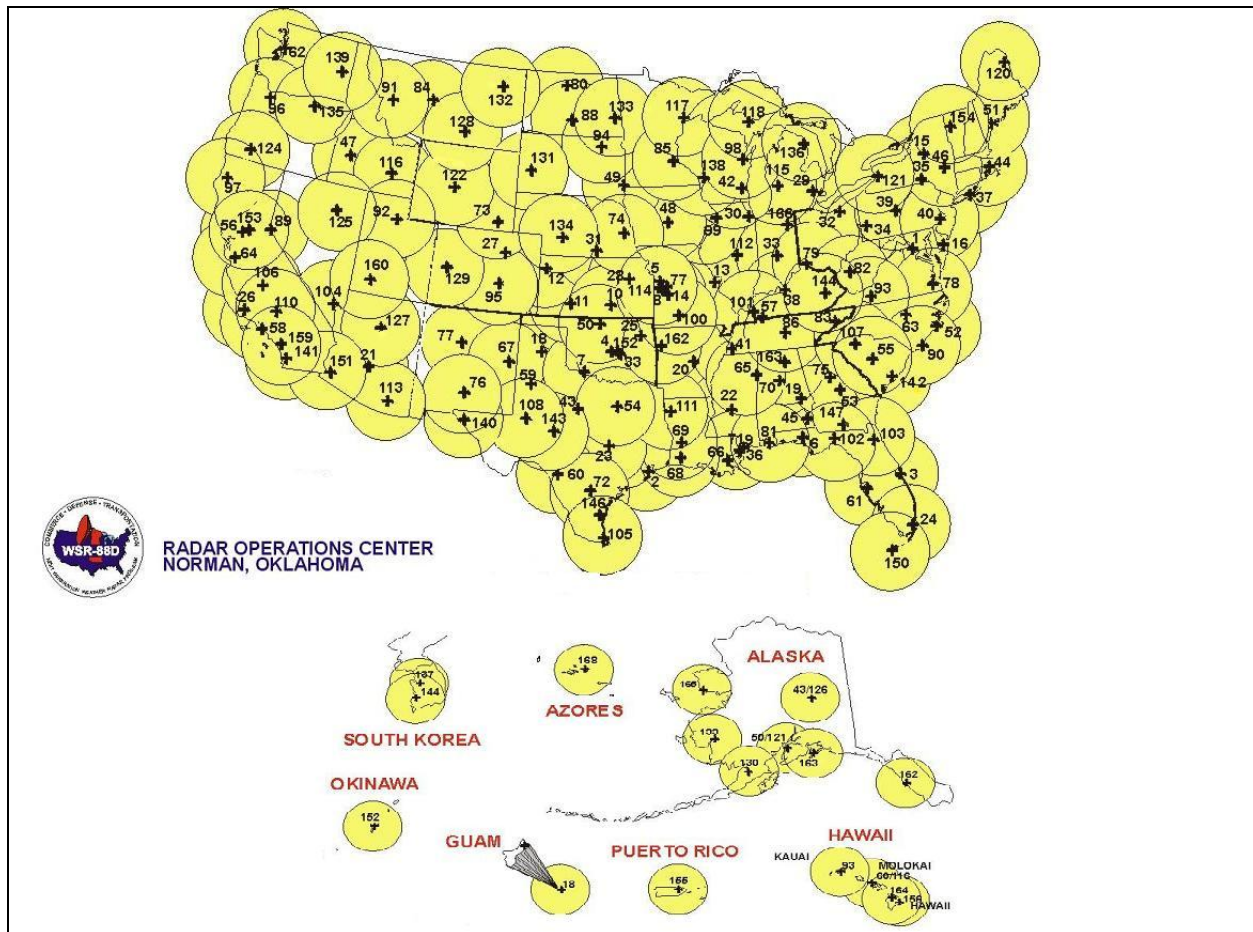
Data feeds are compared against each other, and repopulated if necessary on a daily basis before reaching the NCDC archive. This increases the possibility for a serially complete archive. Data quality control processes include checks on the raw GRIB (WMO, 2001) model data and its associated transmission and file headers to the actual product, thus ensuring the highest possible quality of the data being archived and made available for distribution via NOMADS. NCDC works closely with NCEP if header or data errors are detected. Ingested models are also aggregated by model scale, projection, and forecast projection which, along with locally generated "index" files (a file and variable identifier utility) greatly increases the access speed of requested files or subsets.

NOMADS ingests approximately 250,000 individual grids a day and with these index and file level optimizations, users can gain access to any single model variable within seconds. Additional operational NCDC ingest, archive, and quality control process are also performed including system loading, back-end disk clustering, load balancing and other backup capabilities to form a 24/7 operation.

2.15 Radar Data Server (NEXRAD)

2.15.1 Concept of Operation

There are 159 operational Weather Surveillance Radar-1988 Doppler (WSR-88D) radar systems covering the United States and select offshore areas. The radars have a maximum range of 250 nautical miles. The radars are positioned to maximize geographical coverage and concentrate on areas where the data is most needed. These radars make up the Next Generation Weather Radar system (NEXRAD), which is a joint effort of the US Departments of Commerce (DoC), Defense (DoD), and Transportation (DOT). The NEXRAD network is operated by the NWS Radar Operations Center (ROC) in Norman, OK, and a map of the radar coverage is shown in the following figure:



2.15.2 Technology Architecture / Information Flows

NWS Weather Forecast Offices (WFO) collect data from 155 WSR-88D radars, process the data with the Radar Product Generator (RPG) tool, and send NEXRAD Level II products to the AWIPS National Control Facility (NCF) through the AWIPS WAN. From there the data is distributed back through the AWIPS

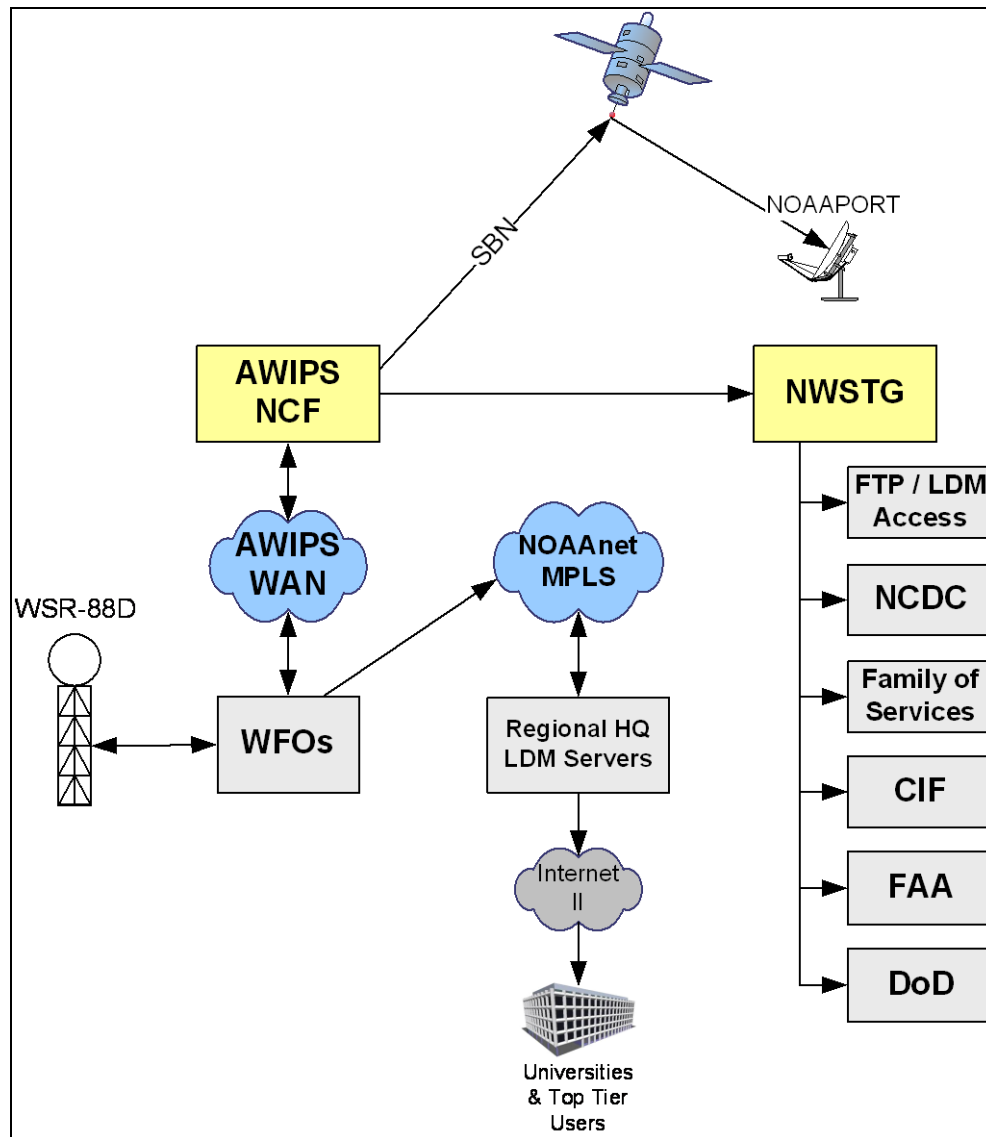
WAN to all WFOs (as well as RFCs and CWSUs), through the Satellite Broadcast Network (SBN) as part of the NOAAPORT service, and directly to the NWSTG, which further distributes the data to multiple centers and agencies. The WFOs also for the data through the NOAAnet MPLS backbone to LDM servers located at the Regional Headquarters where the data is further distributed through Internet II to various universities and top-tier users, typically for research purposes.

The NWS also produces Level III radar products based on data from the WSR-88D radars and 45 FAA TDWR radars and provides access through the Radar Product Central Collection Dissemination Service (RPCCDS). The Level III radar products can either be obtained by directly connecting to the NWSTG for an immediate receipt of the products through an LDM feed or via standard anonymous FTP from the Gateway file servers. Listings of available from the RPCCDS and through NOAAPORT can be found in the following PDF documents on the web:

http://www.nws.noaa.gov/tg/rpccds_radar_products.pdf

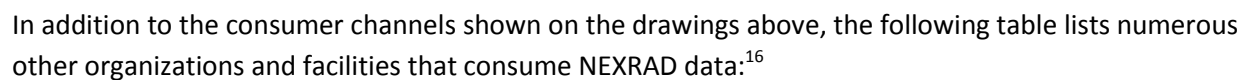
http://www.nws.noaa.gov/tg/noaaport_radar_products.pdf

The figure below depicts a simplified flow of NEXRAD data.



Current NEXRAD data flow

Currently, the NWS is working to change the architecture of the NEXRAD Level II data collection and distribution architecture. The regional aggregation points will be replaced by a central aggregation point (staffed 24/7) with full redundancy at an off-site location (the National LDM Servers). NOAAnet communications will be used to send the data to the central aggregation point(s) resulting in increased reliability of data flow. A representation of the planned Level II dissemination architecture is shown in the figure below:



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FACILITY	RELEVANT RESPONSIBILITY	NEED FOR/USE OF NEXRAD DATA
NWS:		
• NCEP	Issue weather analysis and forecast guidance	Overview information for generation of radar summary products; detailed rainfall information; and high resolution data for mesoscale models.
• SPC	Issue severe convective storm and tornado watches	Low resolution information in storm areas.
• TPC	Issue hurricane watches and warnings	Low resolution information in hurricane areas.
• RFCs	Derive flood forecasts.	High resolution area/precipitation estimates covering river basins.
• NWSFOs/NWSOs	Issue severe weather, flood, and flash flood warnings for local area.	High resolution information on hazardous weather in or approaching local area.
DoD:		
• BWSs	Issue weather warnings and advisories for AF base area.	High resolution information on hazardous weather in or approaching base area.
• AFGWC	Issue weather warnings and advisories where no BWS operating.	High resolution information on hazardous weather where no BWS operating; Low resolution overview information elsewhere.
• NOCDs	Relay weather warnings and advisories in Navy base/station area.	High resolution information on hazardous weather in or approaching base area
FAA:		
• ARTCCs/CWSUs	Disseminate hazardous weather information internally and to other FAA users (e.g., ARTCC, TRACON, and Tower) in ARTCC area of responsibility.	High resolution on hazardous weather in or approaching ARTCC area of responsibility
• ATCSCC	Interface with each ARTCC to establish air traffic flow patterns, enhance flight safety, and minimize delays.	Low resolution overview information on a national basis.
• AFSSs	Provide hazardous weather information within air-to-ground coverage area; provide En route Flight Advisory Service for area of responsibility (if applicable); provide preflight briefings on a national basis.	High resolution information on hazardous weather in or approaching FSS area of responsibility; low resolution information on a national basis.
• TRACONS	Provide hazardous weather information to controllers and pilots.	High resolution current information on hazardous weather in terminal airspace (e.g., gust fronts, down drafts, wind shear, and turbulence), especially on final approach and take-off.

2.16 RIDGE

2.16.1 Concept of Operations

Radar Integrated Display with Geospatial Elements (RIDGE) is a service intended to meet a wide range of needs for customers. Any user with internet access is capable of utilizing this product.

Radar and text products are decoded using the IRIS framework and organized in a Postgis database. The OGC Web Map Service (WMS) is used to serve up the radar data to the end-user. The RIDGE architecture features a 'TileCache' to store recent radar image requests for quick access. RIDGE supports the following standards and formats:

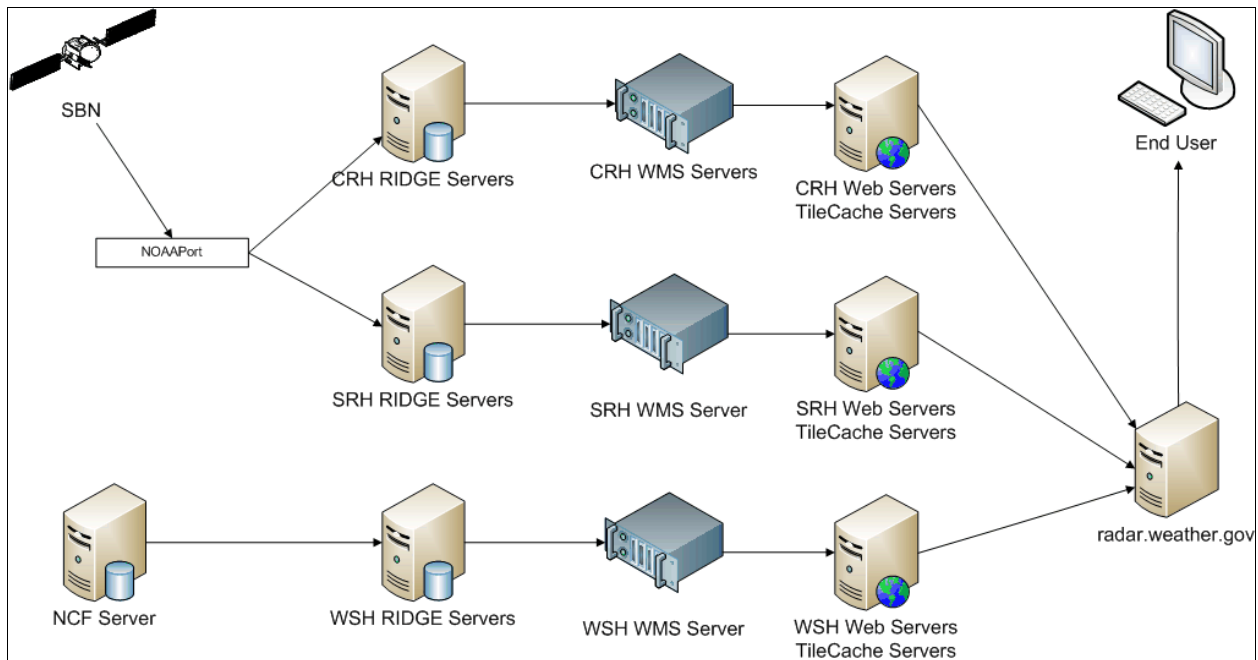
- Geo-referenced PNG and GIF Images
- OGC Compliant GIS Services
 - Web Map Service
 - Web Feature Service
 - Web Coverage Service
- KML
- GML /XML
- GIS compatible shapefiles
- Web interface
- Supported radar formats (level 3)
 - WSR-88D, TDWR, ARSR-4, ASR-11
 - All Radar NOAAPort Products
 - RFC precipitation graphics (one hour)

RIDGE receives radar information through the NOAAPort feed from the WSR-88D Radar Product Generators (RPGs). Geospatial elements are derived from GIS files available from the United States Geographical Service (USGS). The radar images will be generated using Microsoft Visual Basic .NET technology.

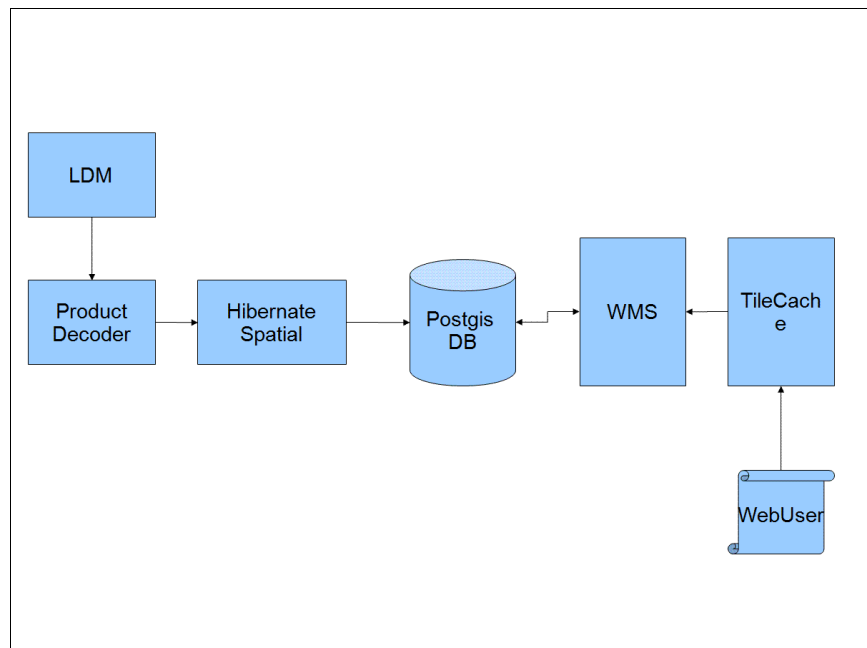
Images presented from RIDGE are in GIF format. These images also have a world file associated with them, enabling GIS users to directly incorporate the radar image into any other GIS data layer. The looping feature of the web pages utilizes a Java plug-in. The plug-in allows the use of multiple image formats which include GIF and PNG, both of which maintain clarity when zoomed. On both the static image webpage and loop webpage, the user can select which overlays are displayed through the use of check boxes located below the image. The static pages contain JavaScript which enables the user to determine both azimuth and distance from a feature that the user selects by clicking on the image.

2.16.2 Technology Architecture / Information Flows

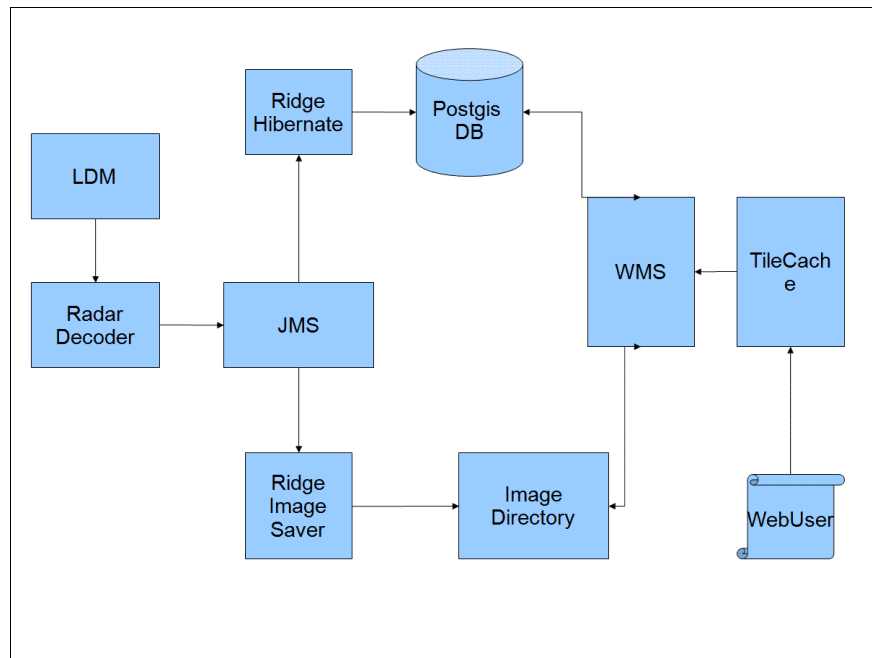
A high-level overview of the RIDGE architecture is presented in the figure below.



For hazard (text) products, the diagram below shows the flow from the product decoder to web user.



For radar data, the figure below depicts the flow from the radar decoder to end-user.



2.17 NSSL/NMQ/WDSS-II

2.17.1 Concept of Operations

The National Severe Storms Laboratory (NSSL) houses 3 systems: 1) the National mosaic and Multi-sensor Quantitative precipitation estimation (NMQ), 2) the Warning Decision Support System – Integrated Information (WDSS-II), and 3) the 3D/4D Radar System. NSSL offers an integrated, real-time, multi-sensor platform to develop, test, and assess advanced techniques in quality control, data integration, application development (in severe weather and precipitation estimation), display, and short-term forecasting. The ingest by NSSL is comprised of radar data, satellite data, NWP data (RUC model), Lightning (NLDN, LMA), surface observations (ASOS, Mesonets), and rain gauge.

The NMQ produces the following precipitation products:

- Reflectivity Products
 - Vertical Profile of Reflectivity, Bright-band Identification
 - Hybrid-Scan Reflectivity (VPR corrected)
- Precipitation Products
 - 1-HR, 3-HR, 6-HR, 12-HR, 24-HR, and 72-HR Precip
 - Radar only, Multi-Sensor, Radar with Gauge Bias Correction
 - Local Gauge Bias
 - Gauge-only Precip
- Precipitation Verification
 - Comparison to Stage-2, Stage-3, Stage-4, HADS (Hydrometeorological Automated Data System), MPE (Multi-sensor Precipitation Estimation)

The NMQ website () keeps a 2 year online archive of precipitation products. The products are used by RFC's and NWS Forecast Offices (FO's) for operational use.

The WDSS-II uses severe weather algorithms to produce the following products:

- 3D Reflectivity Mosaic
 - Automated QC Neural Network
 - VIL, EchoTop, Composite, Isotherms
 - Hail (Maximum Expected Size, Probability, Hail Swath)
 - Kmeans/Segmotion Nowcast, Storm Tracking
 - Storm Classification
- 3D Velocity
 - Vortex Detection & Diagnosis Algorithm (from Azimuhai Shear)
 - Multi-Doppler Wind Analysis
- Multi-Sensor Algorithm
 - Lightning (NLDN & LMA)
 - Near Storm Environment (from RUC numerical model analyses)
 - Satellite

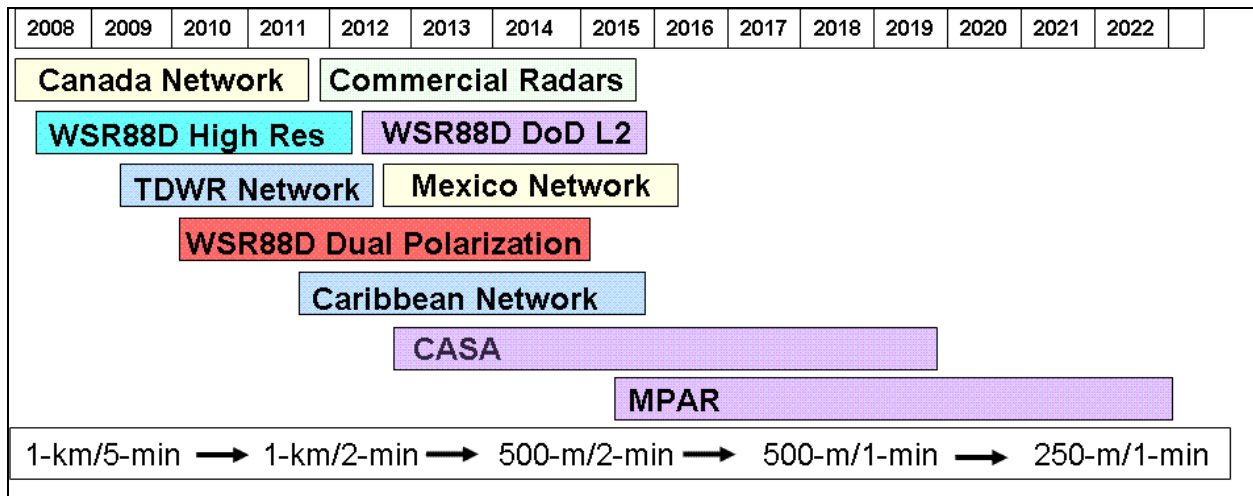
These products are used by NCEP (SPC and AWC) and NWS FO's, CAPS, ESRL, MCAR and Environment Canada for operational use. The WDSS-II website () keeps an archive of automated Hail Swath and Rotation Track information.

Lastly, NSSL has a 3D/4D Radar System that produces the 3D Radar Merger product which has the following features:

- Ingest data from national network of WSR-88D radars.
- Grid resolution of 1km x 1km over the CONUS with 31 vertical levels
- Data streaming in from multiple radars passes through an automated QC to remove non-precipitation echoes.
- Integrate with other meteorological data to generate algorithm products (satellite, RUC model analysis, etc)
- 3D grid and products updated every 5 minutes.

NSSL plans on expanding its server farm to enable production of 0.5km CONUS products every 2 minutes (compared to 1km every 5 minutes) and will support dual polarization algorithms/products as the WSR-88D network is upgraded.

The figure below shows NSSL's future research activities correlating with increasing resolution and frequency of product generation.



2.17.2 Technology Architecture / Information Flows

Currently, the above mentioned NSSL systems produce 1-km CONUS products every 5 minutes. The processing required to execute all of the algorithms is substantial.

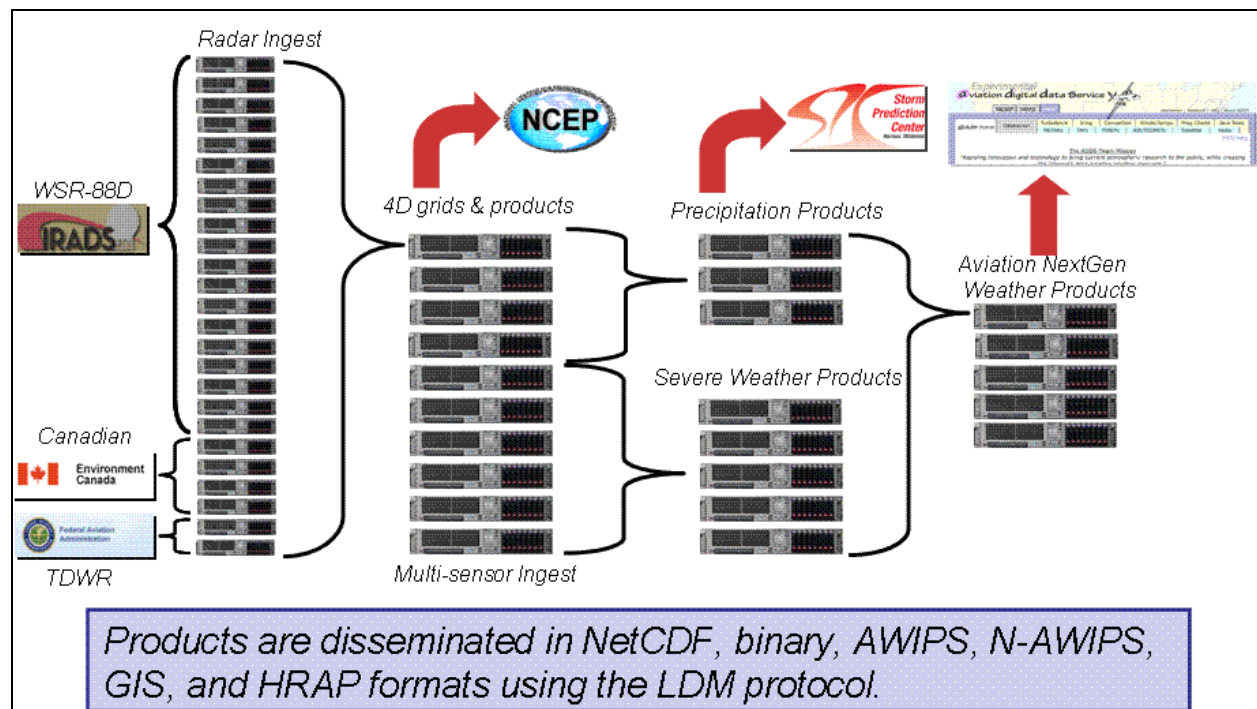
- 1-km CONUS 3D radar observation grid requires approximately 22 servers.
- WDSS-II severe weather products and multi-sensor ingest requires approximately 10 servers
- NMQ products require approximately 16 servers.

All servers run RedHat 64-bit OS.

The radar data ingest portion of the servers consists of:

- Ingest base level 2 data from 158 tri-agency (DOC, DOD, DOT) 10 cm WSR-88D radars.
- Ingest base level data from 33 5-cm radars from Environmental Canada/NCDC
- Ingest base level data from two TDWR's using direct connections.
- Ingest commercial radars in addition to experimental radar systems.
- System optimized for quick access to radar systems and radar networks.

The entire NMQ/WDSS-II processing system is composed of 2 Quad-Core AMD Opteron processors (2.9 GHz with 32 GB RAM) Linux servers. The diagram below shows radar inputs, different data processing tiers, and the direct users of NSSL's products.



2.18 NOAA/NWS Supporting Infrastructure Systems

2.18.1 Telecommunications Operations Center (TOC)

The NWS Telecommunications Operations Center (TOC) is a critical component in the collection and dissemination of weather data both domestically and internationally and will play a key role in support of the 4-D Weather Cube.

The TOC consists of the following primary components that will be discussed separately in the following sections:

- Central Data Switching System
- ASOS Monitoring Center (AOMC)
- AWIPS Network Control Facility (NCF)

2.18.1.1 Concept of Operation

Central Data Switching System

The National Weather Service Telecommunications Gateway (NWSTG) is the Central Data Switching System and is managed by the Office of the Chief Information Officer (OCIO). The NWSTG operates and ensures continuous acquisition and dissemination of NOAA NWS and other domestic and foreign weather related data and products. The central switching system of the NWSTG controls the exchange of data with remote locations as well as other internal systems. The international switching centers are on the Main Trunk Network (MTN) of the WMO's Global Telecommunication System. This system also

operates the Operational Meteorological (OPMET) data bank and contains aviation METAR, TAF, and SIGMET data. The OPMET data bank supports the International Civil Aviation Organization (ICAO) World Area Forecast Center (WAFC). The NWSTG directly supports the Washington WAFC with the other WAFC being Exeter, UK.

The NWSTG exchanges a large amount of weather information and data with other government departments, primarily the FAA and the DoD. The NWSTG receives a large amount of observational data from the DoD and provides back a variety of weather products. The NWSTG also is connected to the FAA Bulk Weather Telecommunications Gateway (FBWTG) for distribution of gridded model weather forecasts and airborne weather observations used by the FAA's Weather and Radar Processor (WARP) and the Integrated Terminal Weather System (ITWS).

The NWSTG also operates several web servers and file servers. The web and file servers store all nationally-generated forecast products and globally received observational data. The web service (HTTP) provides browser access to retrieve data and forecasts and is accessible by the general public through the Internet Farms described in a later section. The file servers (TGFTP) provide a file transfer service for retrieval of operational model forecasts and observational data and, even though accessible through the Internet by anyone, are typically used by commercial and government users, as well as international users, to retrieve weather data for further processing. The TGFTP service is used fairly heavily by several commercial users to augment their dedicated Family of Services (FOS) connections.

ASOS Monitoring Center (AOMC)

The AOMC constantly monitors the quality of the sensors in thousands of Automated Surface Observation Systems (ASOS) sites across the United States. In addition to constantly observing and reporting local weather elements, ASOS observation stations also perform self tests on system status. When a problem is detected, ASOS observing stations append "maintenance flags" on the next observation report. This flag serves as a trigger to alert the AOMC of a possible system malfunction. The AOMC can then dial into the site and diagnose the cause of the trouble. When maintenance is needed, the AOMC notifies the appropriate maintenance point of contact for action. The AOMC maintains the master database of ASOS site configuration information consisting of eleven (11) data files for each site containing about 4000 specific items that define everything about the site from sensor inventory, AOMC telephone numbers, sensor configuration, passwords, parameters needed to translate pressure readings, and even the digitized voice identification of its airport name. This database is automatically downloaded to the site when the ASOS is cold-started and each time any site database parameters are changed, the change is automatically communicated to the AOMC. In addition, the AOMC provides access to a precision time source linked to the National Institute of Standards and Technology (NIST) in Boulder, CO, which keeps all ASOS system clocks synchronized. For commissioned sites, changes to ASOS site specific databases are also provided to the National Climatic Data Center (NCDC) where they are archived with the official observations from the site. Certain changes to the site's database may have an impact on the resulting observation and users need to know when the database changes occurred.

AWIPS Network Control Facility (NCF)

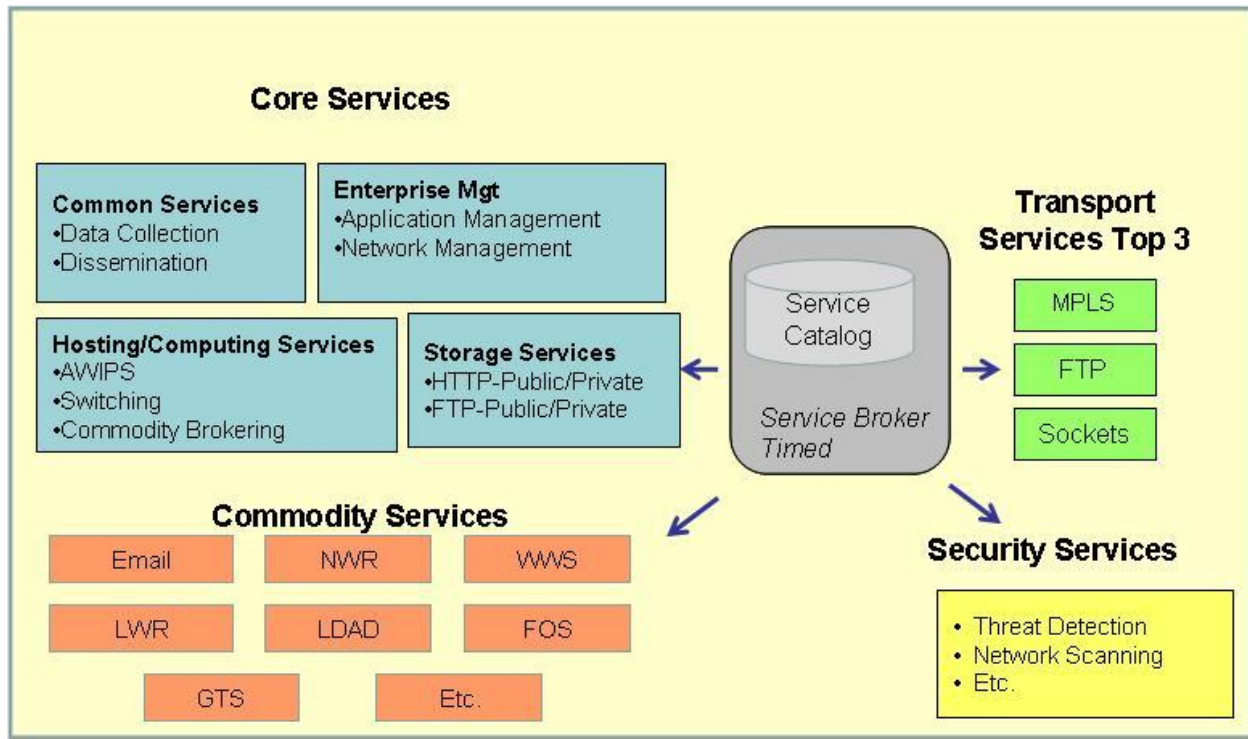
The AWIPS NCF is an important center for collection and dissemination of a multitude of weather information serving a large number of end users. The NCF is collocated with the NWSTG at NWS headquarters in Silver Spring, MD, and serves as the central collection, processing, dissemination, and monitoring facility for the Advanced Weather Interactive Processing System (AWIPS).

AWIPS is an interactive, decision-support and analysis tool that integrates all meteorological, hydrological, satellite, and radar data into one computer workstation. AWIPS allows NWS forecasters the interactive capability to view, analyze, combine, and manipulate large amounts of graphical and alphanumeric weather data to prepare and issue more accurate and timely forecasts and warnings. AWIPS terminals are located at WFOs and RFC's as well as remote AWIPS displays that form the Center Weather Service Units (CWSU) located at twenty-one FAA Air Route Traffic Control Centers (ARTCCs).

The NCF operates by collecting/receiving weather information messages through the AWIPS WAN from the WFOs and NESDIS, as well as NCEP data received locally through the NWSTG. The AWIPS NCF manages the AWIPS WAN and the Satellite Broadcast Network (SBN). Data streams delivered through the SBN are called NOAAPORT.

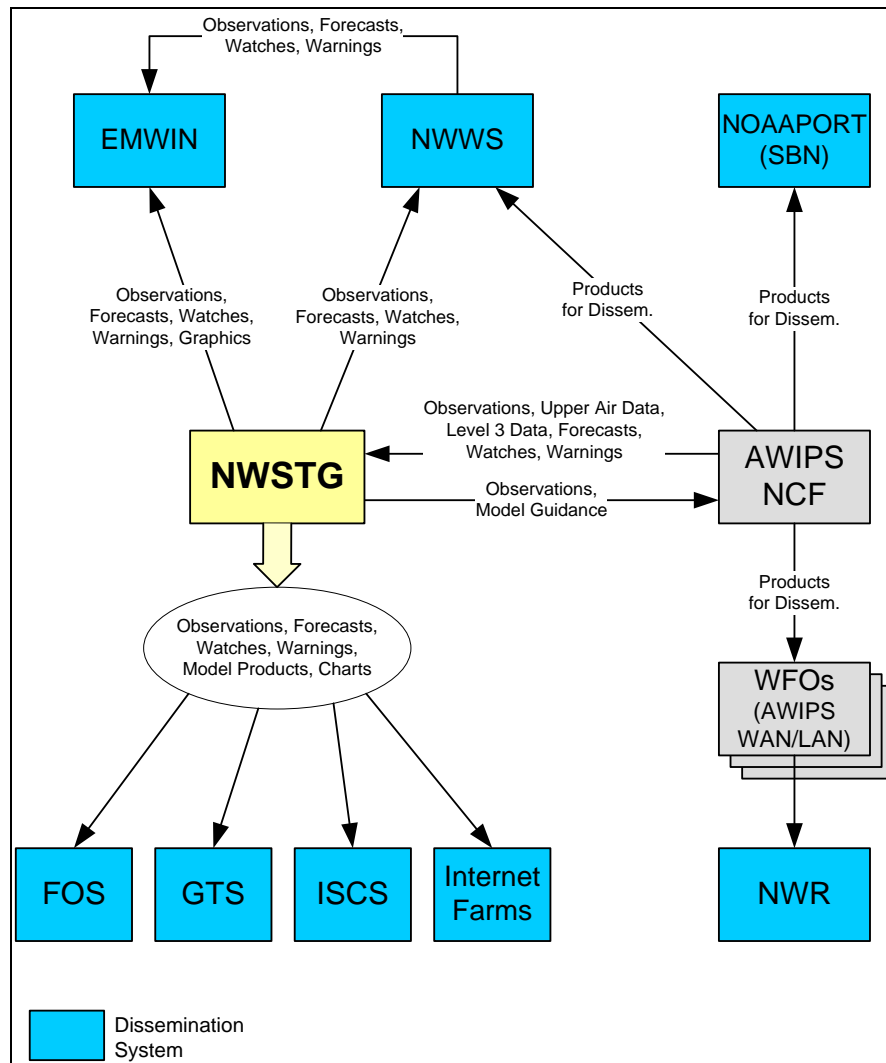
2.18.1.2 Technology Architecture / Information Flows

A high level overview of the TOC is presented in the figure below.

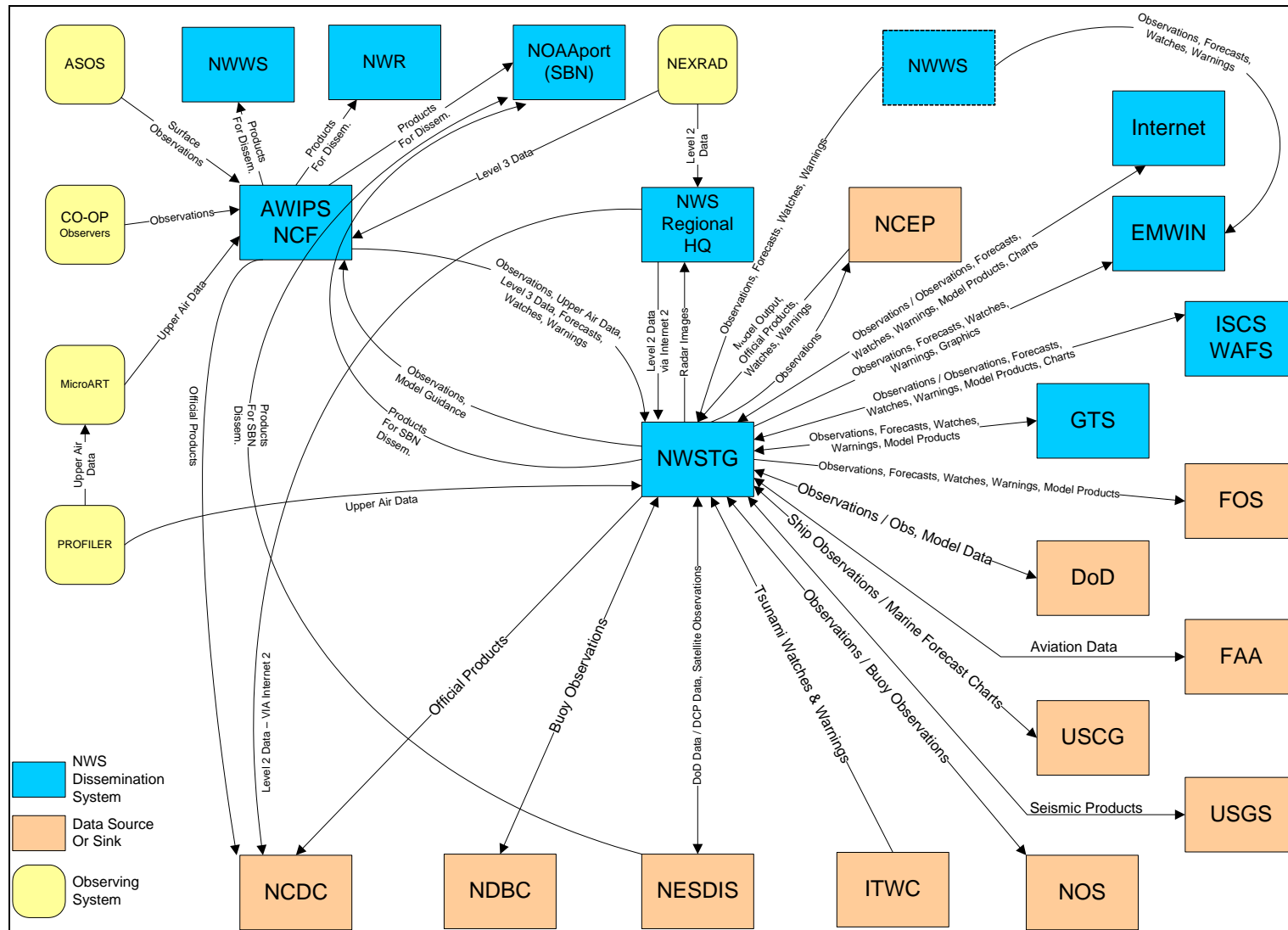


Central Data Switching System

The Central Data Switching System, consisting of the NWSTG, is a conglomeration of servers, computers, routers, firewalls, satellite terminals, and associated applications and communications infrastructure located within the NWS headquarters in Silver Spring, MD. The following figure shows the relationship between the primary NWSTG and other NWS dissemination systems.



The following figure shows the overall information flow in and out of the NWSTG and includes both NWS systems as well as external sources and data users.



NOAA NWS has recently implemented a backup facility to operate in parallel with the NWSTG. This backup gateway is located at Mt. Weather, VA. Connectivity to the backup gateway is through NOAAnet and it mirrors all data resident at the NWSTG in Silver Spring. The backup gateway is being upgraded in order to operate as a fully redundant hot standby for the primary NWSTG. Previously, the requirement was for the backup gateway to be brought up into operation within 12 hours, but the latest performance requirement is for instant fail over and assumption of the full traffic load. Additionally, the backup gateway is being designed to be able to support full operations for a period of at least 30 days.

ASOS Monitoring Center (AOMC)

ASOS are installed at more than 900 airports across the country and have the primary function of providing minute-by-minute observations and generating the basic Aviation Routine Weather Report (METAR) and Aviation Selected Special Weather (SPECI) report. ASOS detects significant changes, disseminating hourly and special observations via the networks. Additionally, ASOS routinely and automatically provides computer-generated voice observations directly to aircraft in the vicinity of airports, using FAA ground-to-air radio. These messages are also available via a telephone dial-in port. ASOS observes, formats, archives and transmits observations automatically. ASOS transmits a special report when conditions exceed preselected weather element thresholds, e.g., the visibility decreases to less than 3 miles.

ASOS reports are sent from the observing station via "long-line" connectivity to the controlling WFO and the NWSTG. Communications back to the ASOS station from the AOMC is done through dial up circuits.

ASOS was developed with a considerable array of self diagnostics that run almost constantly and provide the first level of ASOS quality control. The algorithms associated with each diagnostic append a Maintenance Check Indicator (\$) to the METAR/SPECI report when certain error conditions are detected and provide indication of missing parameters when the value of a parameter is decided to be suspect. An application running at the NWSTG sends a list of all ASOS observations that contain the special error codes to the AOMC. The Gateway system also checks for missing observations from ASOS sites. At scheduled times, the NWSTG application compares the observations received against the list of observations that should have arrived and sends the "missing sites" list to the AOMC.

Lastly, the AOMC receives telephone calls from ASOS users who believe that some problem exists. The "1-800" telephone number has been widely distributed and the AOMC receives calls from private users, as well as from FAA and NWS staff.

When the AOMC receives notification that there is an apparent problem at a site, the first order of business is further diagnosis of the problem. In most cases, the AOMC will dial into the troubled site for a more detailed diagnosis. Just as the ASOS automatically performs an impressive array of tests, the AOMC has a comprehensive suite of additional diagnostic tools as well as the capability to remotely clear many problems.

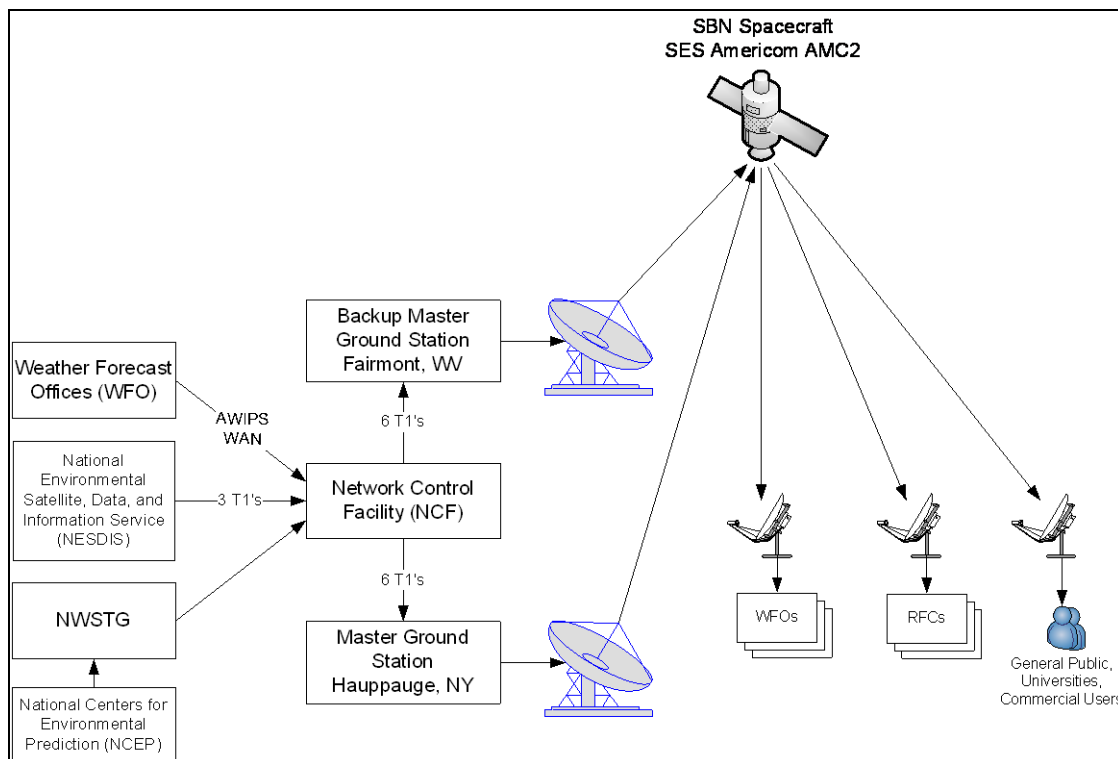
Exchange of ASOS METAR messages between the FAA and NWS communications networks occurs through the NWSTG. ASOS METAR messages, SHEF data, and Daily Summary and Monthly Summary Messages from both FAA and NWS locations are additionally available to other users through the NWSTG.

AWIPS Network Control Facility (NCF)

The system architecture consists of the Network Control Facility (NCF), Satellite Broadcast System (SBN), wide area network (WAN), Weather Forecast Offices (WFOs), River Forecast Centers (RFCs), National Centers, and the NOAAPORT Receive System (NRS). The SBN is a key component of the AWIPS communication network that feeds data from the NCF to each AWIPS site (WFOs and RFCs), and distributes information among the AWIPS sites.

The NOAAPORT broadcast system provides a one-way broadcast of a comprehensive suite of NOAA NWS environmental data and information in near-real time. Information is distributed in WMO formatted messages.

NOAA data is collected by a wide variety of stations and observing systems and are sent to the NOAA NWS Telecommunications Gateway (NWSTG) in Silver Spring, Maryland. Weather data is collected by GOES satellite environmental sensors and NOAA NWS observing systems, and processed to create products. The products are fed to the AWIPS NCF, which routes the products to the SBN NOAAPORT uplinks for broadcast. Nearly all of the data that is collected by NOAA NWS will be available for use on the NOAAPORT channel.



In addition, the AWIPS program has purchased Ku band VSAT terminals and services to be used for disaster recovery when a WFO loses its terrestrial WAN connectivity. There are four portable, or flyaway, 1.2 meter iDirect terminals that can quickly be deployed to offices that suffer a disaster or other event that renders their primary AWIPS terminal unusable due to lack of connectivity.

2.18.2 NOAAnet

2.18.2.1 *Concept of Operation*

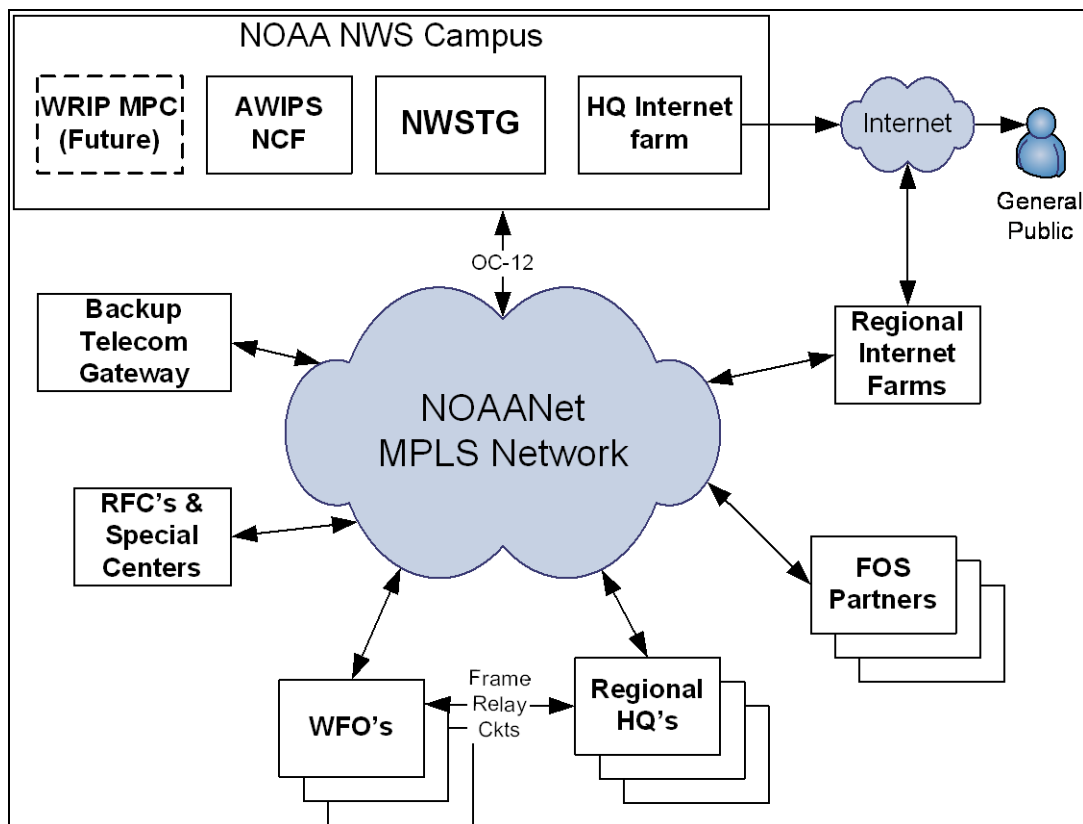
NOAAnet is the new WAN infrastructure that is envisioned as providing the majority of network connectivity for NOAA NWS and NOAA as a whole. The initial implementation of NOAAnet is being built using the Multi-Protocol Label Switching (MPLS) network provided by one of the large telecommunications service providers. The MPLS network will provide the backbone for AWIPS, essentially replacing the AWIPS WAN as well as NWSNet. All regional headquarters and all WFOs have been connected to NOAAnet with their own MPLS routers. The WFOs have also migrated to direct connectivity into the MPLS “cloud” with their own router. The network will allow for versatile layering of applications through the implementation of separate VPN tunnels for various users and applications. MPLS networks offer several classes of service so that mission critical applications and those requiring low latency, such as voice and video, can be given highest priority for transport through the network.

Ultimately, all NWS and NOAA employees will be end users of NOAAnet as it assumes the role of NOAA’s primary information exchange network. There will also be varied external users as different NOAA NWS services and applications are migrated onto NOAAnet. Some anticipated external end users include FEMA, DHS, and FAA.

2.18.2.2 *Technology Architecture / Information Flows*

The primary architecture of NOAAnet is a commercially-provided national MPLS network. Each NOAA line office and/or facility connected to NOAAnet has a local MPLS router that connects the facility into the MPLS cloud where traffic is routed through various virtual LANs (VLAN), private networks (VPN), and private point-to-point circuits. Traffic bandwidth and priority for each connected node is controlled by the service provider in accordance with service level agreements (SLA) with NOAA.

All types of data that are produced and/or disseminated will be capable of traversing NOAAnet. The primary transport data format will be TCP/IP within MPLS. Any application data formats can be accommodated on the MPLS backbone. The following figure shows the high-level relationship of various NWS components connected via NOAAnet.



After hurricane Katrina a Ku-band satellite back-up system was implemented at 53 WFO sites, primarily coastal and Central Region sites. Eventually, it is planned that there will be a Ku-band earth station back-up at every WFO site, which is pending additional funding. This system is commercially contracted and provides a dedicated T 1 circuit for disaster recovery operations in the event a WFO loses all other enterprise communications. In that event, the NWS instructs the service provider regarding prioritization of traffic.

2.18.3 Consolidated Internet Farms (CIF)

2.18.3.1 Concept of Operation

Regional Internet Farms were established as early as 1995, and in 2001 there was significant concurrent development of NOAA NWS regional Internet farm infrastructure to host web pages and weather data for general Internet consumption. NOAA NWS deployed a set of mirrored databases on the NOAA NWS regional headquarters-based Internet Farms containing all active watches, warnings, and alerts as well as radar and other weather information.

There is a very large range and amount of weather information available on the NOAA NWS Internet farms, the websites of NOAA NWS headquarters, and the National Centers for Environmental Prediction (NCEP). All warning, watches, and alerts are available in text formats as well as gridded data, radar and

satellite images, model guidance data, and a range of climatological and hydrologic data and weather products. Data on the Internet Farms obviously comes from a wide range of sources including the NWSTG, WFO's (AWIPS), special centers, CWSU's, etc. The NWS Internet farms are currently the only location on the Internet for key hydrological data, including river flood stage data through the Advanced Hydrological Prediction System (AHPS).

The NOAA NWS web sites average more than 6 million users per day over the long term. Weather events can spike usage to much higher numbers in the range of 30-40 million users per day during major hurricane events. Growth of this service continues at a rapid pace, sometimes doubling every 12 months.

The range of users of the web program is extremely diverse; from the general public to emergency managers. NOAA NWS web pages are continuously monitored at Department of Homeland Security emergency operations centers. Emergency managers across the country - especially those in financially restricted counties - use NOAA NWS websites to monitor both NOAA NWS products and radar displays to better help them manage resources. Media outlets across the country also use the web program not only to monitor real time events, but also to provide short and long term forecasts, as well as to find climate information and even display NWS radar web displays during broadcast. A large number of small businesses use weather information on NOAA NWS websites to manage resources such as construction crews and farm workers. Many vendors have created applications that consume XML data services automatically in order to assist automation. An example of this is building environmental controls that access gridded forecast data to assist heating and cooling systems, reducing overall energy use. The general public uses NOAA NWS web pages to manage numerous aspects of daily life.

2.18.3.2 Technology Architecture / Information Flows

At the end of 2008, the NWS was operating six Internet farms. Over the past couple years, the Internet Farms are being consolidated into three Internet farms: one at NWS HQ in Silver Spring, MD one at Kansas City, MO and one at Fort Worth, TX. These Consolidated Internet Farms (CIF) operate continuously in a globally load balanced configuration with a designed availability of 99.9%. Each farm is also locally load balanced with a designed availability of 98.5%. Each farm is also locally load balanced with caching servers, web servers, NFS servers, database servers, and data processing systems.

A primary purpose of the CIF infrastructure is to provide mirrored data sites throughout the US and to load balance data traffic. This will continue to improve NOAA NWS's overall ability to provide data during periods of high demand, such as during extreme or widespread weather events.

Each Internet farm will be capable of handling at least 50% of the total web traffic in order that any two can handle all the traffic if one suffers a complete failure of some kind. From a backup perspective, this configuration of three sites versus two sites allows for each to be scaled for 50% of the traffic versus 100%, and allows for somewhat less stringent redundancy within each site as each site's availability requirement is lower than in a two site configuration.

- Each farm has 14 front end web servers, two web object caches to serve public requests.
- Each farm has a five node MySQL cluster.
- Each farm has about 20 systems dedicated on the back end to processing, parsing, etc., of raw NWS data.
- Each farm has two NFS file servers, about 4 Tb total.
- XMPP Cluster (2/3 servers).

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Part of NOAA NWS's efforts with the regional Internet farms has been to consolidate URL domain names and to provide for a more homogenous presentation of national and regional websites. With this have come efforts to standardize coding and presentation methods. Facilitating this are two pre-existing XML formats, Really Simple Syndication (RSS)/ATOM, and Common Alerting Protocol (CAP). RSS/ATOM are lightweight XML formats designed for sharing headlines and other Web content and CAP was developed by sections of the emergency management community as a standard format for the exchange of alert messages. Currently all NWS watch, warnings and advisories are transposed into CAP 1.1 format and made available via the HTTP protocol for download. This serviced is expected to be declared official in late 2009.

The regional Internet Farms are fed by the AWIPS Wide Area Network (WAN) and NOAAPORT.

2.18.4 Web Operations Center (WOC)

2.18.4.1 *Concept of Operation*

This section is still under investigation.

2.18.4.2 *Technology Architecture / Information Flows*

This section is still under investigation.

2.18.5 Inter-Regional Integrated Services (IRIS)

2.18.5.1 *Concept of Operation*

The National Weather Service Inter-Regional Integrated Services (IRIS) database is an object-oriented database management schema typically used by GIS applications. IRIS will be a central collection and distribution point for many types of information used by NWS personnel, including information on contacts, requirements, outreach, weather events and products, verification, and geospatial information. Using existing technologies, it is revolutionary in that it can replace a multitude of programs, databases, and data formats with a single structure and location where this information is stored. This standardization will then easily facilitate sharing of information between programs and offices as well as between offices and regional or national headquarters, improving data flow, especially during service backup situations. Planned functionality will improve situational awareness of forecasters and management by including enhanced mapping capabilities to increase the accuracy of event reports, preliminary verification, simple product generation in multiple formats, and a greatly increased customer service interface from which forecasters can easily determine if forecast weather will have an impact on particular NWS stakeholders.

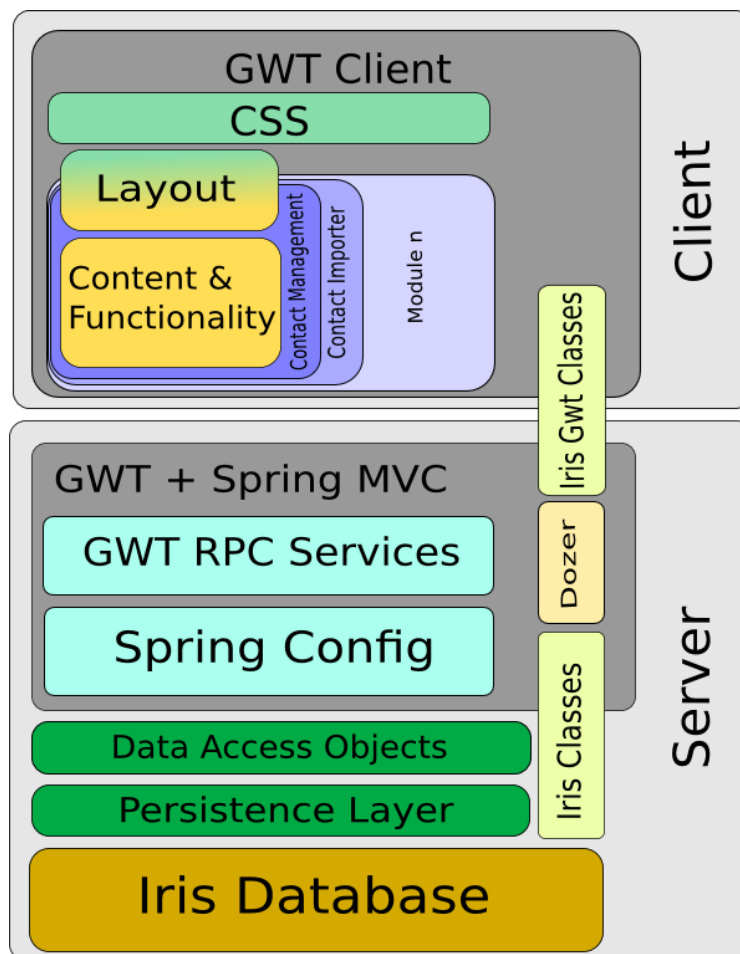
Using a single source such as the IRIS database to generate multiple products will help ensure the most current and accurate information is being used in NWS products. Examples of products which may be generated using IRIS include precipitation summaries, Local Storm Reports, and snowfall maps. Additionally, pulling the data from a single source will also allow for generation of products in various formats including, XML, KML and GIS enabled formats.

Applications already making use of IRIS include RIDGE2, the National Fire Page (warning layer), Central Region KML Google Earth display, iNWS, and SevereClear with NWSChat planned for integration.

2.18.5.2 Technology Architecture / Information Flows

IRIS is based on a Java object model framework that represents NWS data in object oriented code and employs data access classes to write/retrieve objects to/from the database. Initial IRIS framework applications include a product decoder to break down and store NWS products (products are broken down and stored in their atomic parts) and a Web application front-end under development.¹⁸

The basic IRIS components are shown in the figure below:



¹⁸ This section was taken from the *Inter-Regional Integrated Services (IRIS)* presentation; Darone Jones, Project Lead; NOAA System of Systems Workshop, October 6, 2009.

The **IRIS back-end** has the following characteristics (which employ similar technologies that are being implemented in AWIPS II):

- Java Enterprise Edition (J2EE) - Supports development of applications for enterprise-wide sharing of information
 - Uses existing open source frameworks
 - Spring Framework
 - Hibernate
 - Tomcat web server
 - Java Messaging Service (JMS)
- PostgreSQL + Postgis
 - Relational database with a spatial data extension
 - Spatial data stored along with attribute data whenever possible
 - Provides traditional SQL data querying plus powerful GIS analysis
 - Provides a standard data source for many GIS clients (ArcGIS, Udig, GeoServer, etc.)

The **IRIS front-end** has the following characteristics:

- Client applications can be web-based or desktop
- Team's initial client is web-based (internal) – IRIS Web
 - Google Web Toolkit
 - Builds highly interactive and responsive (desktop-like) AJAX web applications
 - Allows web developers to create and maintain complex JavaScript front-end applications in Java
 - Use favorite development software (NetBeans, Eclipse, etc.)
 - Java debugging and profiling

IRIS Web functionality will have the following characteristics:

- Web based GIS, all data is geo-referenced
 - Contact management
 - Add, edit, display
 - Weather concerns
 - Define weather impacts/thresholds for geographic areas
 - Integrates societal impacts into the warning process
 - Existing WWA product integration
 - Storage and display
 - Storm reports
 - Log reports from contacts

- Relate reports to WWA products
- Product generation (LSR,PNS, SPS)
- Storm surveys (geo-referenced damage points, photos/videos, meta-data)
- Store/relate weather information from social networking
- Situational awareness display
 - Queryable mashup of all data using a map display (live and archived)

2.18.6 Consolidated Aviation Web Services (CAWS)

CAWS is a consolidation of web-based NWS aviation weather dissemination systems such as AviationWeather.gov, the Aviation Digital Data Services (ADDs), and the International Flight Folder Document Program (IFFDP).

2.18.6.1 Concept of Operation

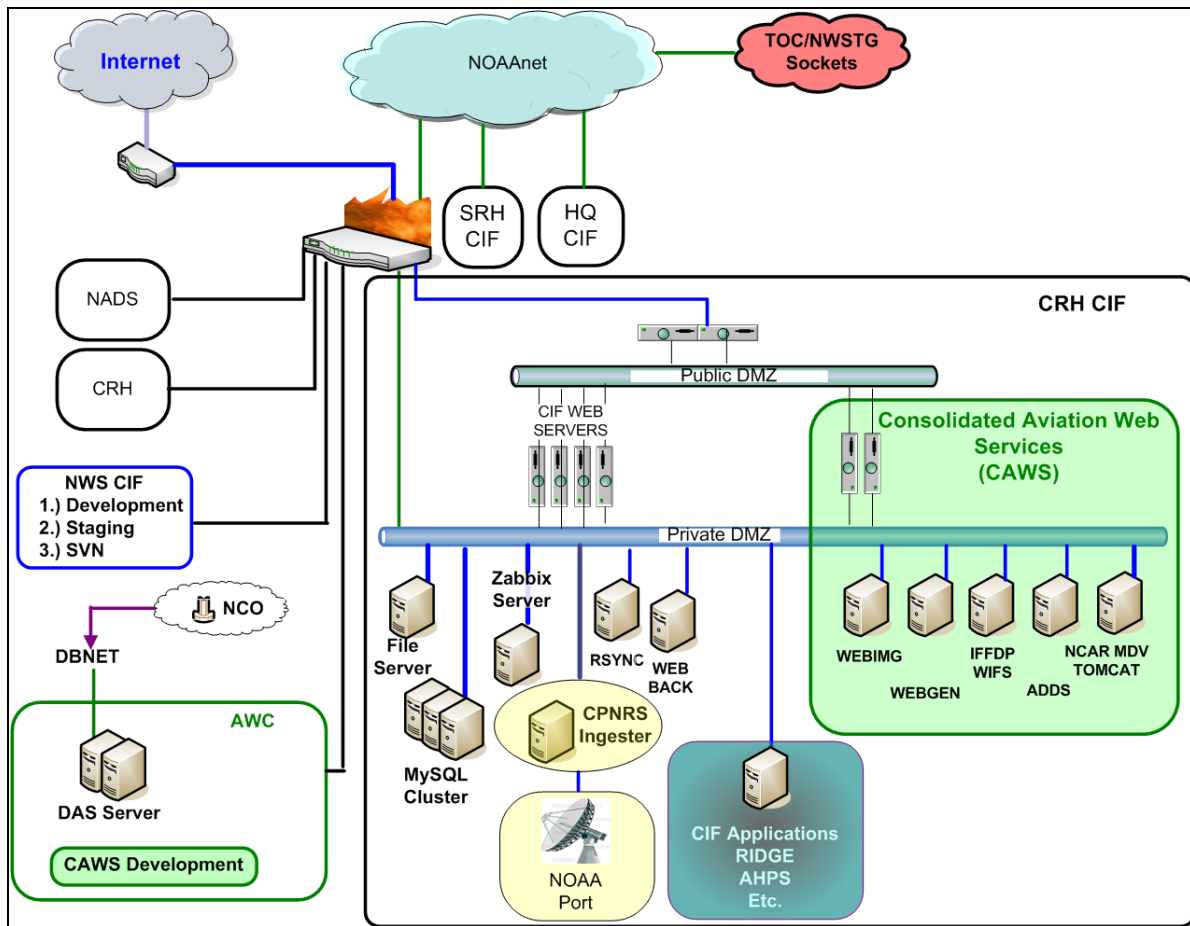
CAWS has been established as the overarching web service consisting of all web outlets offered by the Aviation Weather Center (AWC). These include:

- Aviation Digital Data Service (ADDs)
- International Flight Folder Document Program (IFFDP)
- Aviationweather.gov
- WAFC Internet File Services
- WAFS Web Services

As a primary web infrastructure for the dissemination of weather to the aviation community, CAWS is seeking to gain FAA Qualified Internet Communication Provider (QICP) certification.

2.18.6.2 Technology Architecture / Information Flows

CAWS is in the process of migrating all operations to the three NWS Consolidated Internet Farms (CIF) and has been recently re-architected to gain greater scalability and to separate Web, content generation, file, data, and database services onto separate computing platforms. Within the framework of the CIF, and particularly in the first installation at the Central Region CIF, is depicted below.



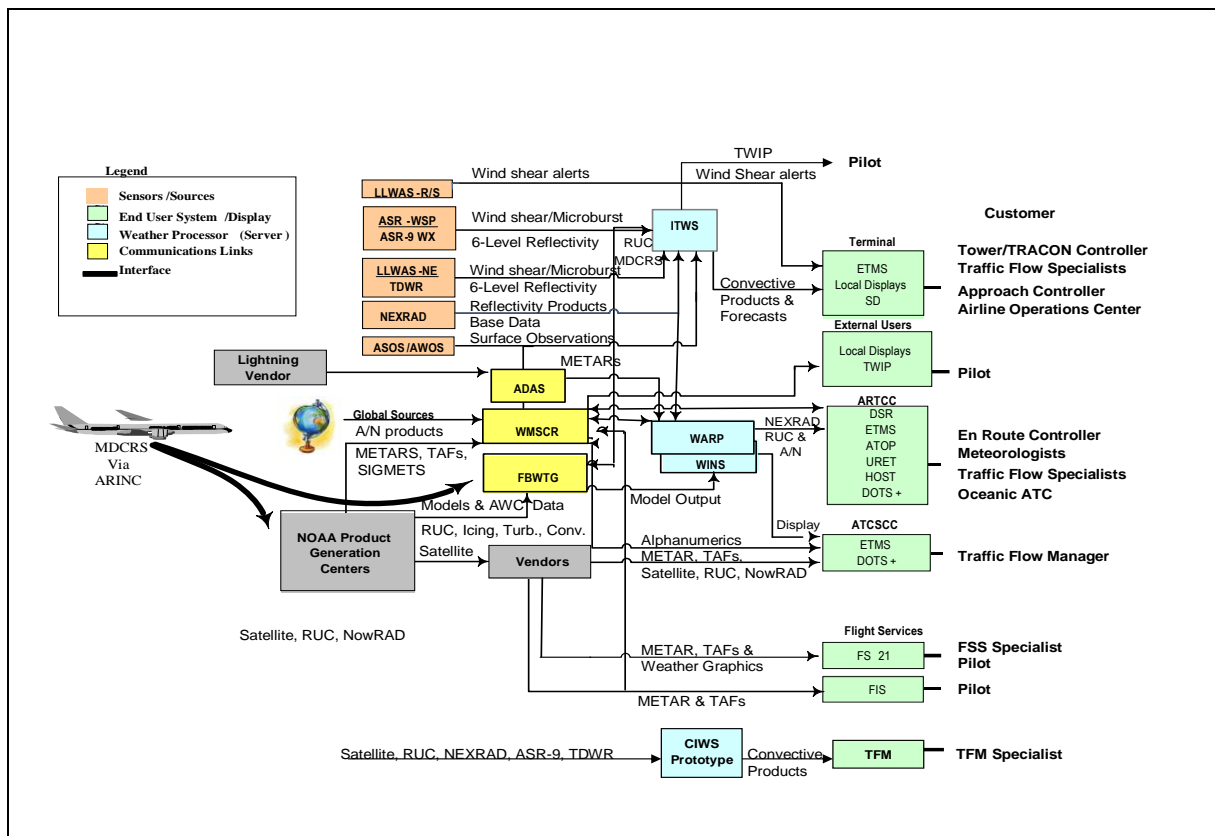
The complete implementation of CAWS at all of the three CIF will take advantage of the geographical redundancy and load balancing of the CIF architecture to achieve high availability for the associated aviation weather services.

3 FAA Weather Systems

The FAA weather systems descriptions provided in this section have been derived primarily from the following sources:

- FAA Product Flows spreadsheet
- NextGen IOC Weather Data Flow and 4-D Weather Cube Service Adaptor Plan (May 15, 2009)
- NAS Architecture Roadmap (December 26, 2007)
- NAS Weather Functional Analysis Workgroup Report (August 30, 2004)
- JPDO ATM Weather Integration Plan (April 22, 2009)

The figure below presents a summary of current key weather information flows and weather-related systems utilized by the FAA users.



The figure includes the following categories of information, systems, and users:

- Sensors / sources
 - LLWAS
 - ASR/WSP
 - TDWR
 - ASOS/AWOS
 - NEXRAD
- End user systems, by location include
 - Terminal
 - ETMS
 - Local displays (e.g., ACE-IDS)
 - SD
 - ARTCC
 - DSR
 - ETMS
 - ATOP
 - URET
 - HOST
 - DOTS+
 - ATCSCC
 - ETMS
 - DOTS+
 - Flight Services systems
- Communications links
 - ADAS
 - WMSCR
 - FBWTG
- Weather Processors
 - ITWS
 - WARP/WINS
 - CIWS
- External sources
 - Lightning data vendors
 - NOAA product generation centers
 - Other vendors providing NOAA products
 - MDCRS
- Users / Customer
 - Pilots
 - Terminal
 - Tower / TRACON controller traffic flow specialists
 - Approach controller
 - Airline Operations Center
 - ARTCC
 - En Route controller
 - Meteorologists
 - Traffic flow specialists
 - Oceanic ATC
 - ATCSCC
 - Traffic flow manager
 - Flight Services
 - FSS specialist
 - Pilot

○ TFM

▪ TFM specialist

The FAA Product Flows spreadsheet details the flow of specific weather data amongst the various FAA and FAA-external weather-related systems planned in the NextGen timeframe.

The sections that follow describe in more detail these systems and the various data flows, both current, and future.

3.1 ASOS/AWOS

3.1.1 Concept of Operations

The Automated Weather Observing System (AWOS) and Automated Surface Observing System (ASOS) automatically measure, process, format, and broadcast various elements of surface weather observations. Weather elements measured include the following:

- Altimeter setting
- Temperature
- Present weather (e.g., thunder (lightning), rain, freezing rain, drizzle, freezing drizzle, snow, sleet, fog, mist, haze, freezing fog, blowing dust)
- Dew point temperature
- Precipitation amount
- Wind (speed, direction, gusts)
- Cloud height and coverage
- Visibility

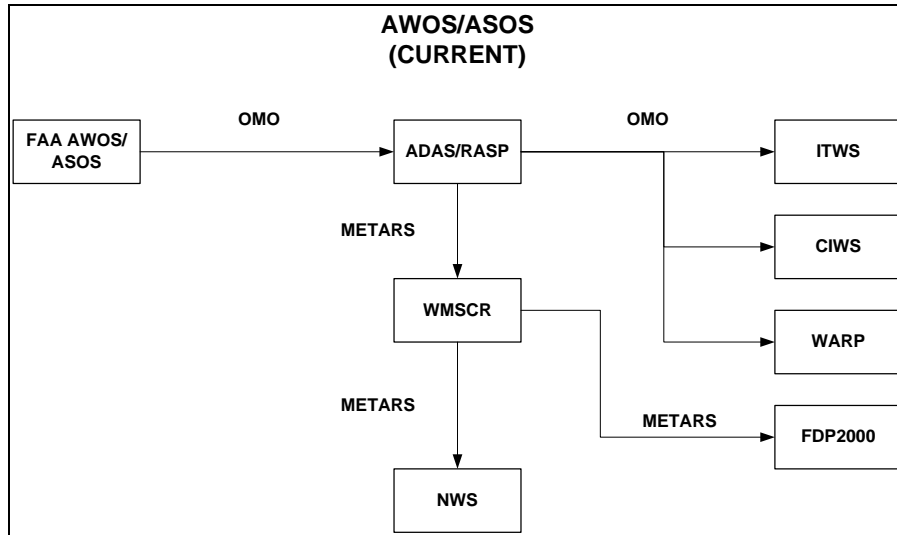
Additionally, at some airports, automated surface observations are supplemented by manual observations taken by Contract Weather Observers (CWO) of the physical weather elements that cannot be measured automatically (e.g., cloud type). The observer appends this additional information to the ASOS observations.

FAA AWOS and ASOS observations are formatted by the Automated Surface Observing System Data Acquisition System (ADAS) into Aviation Routine Weather Reports (METAR) and Special Meteorological Aviation Reports (SPECI) formats. Pilots require a METAR from the destination airport to file a visual flight rules (VFR) flight plan and also one from an alternate airport when flying under Instrument Flight Rules (IFR). As an integral data source for numerical weather prediction models, METARs and SPECIs are also required by the NWS for the generation of the Terminal Aerodrome Forecasts (TAFs). NWS also operates numerous ASOS sites that generate observations and encoded METARs.

3.1.2 Technology Architecture / Information Flows

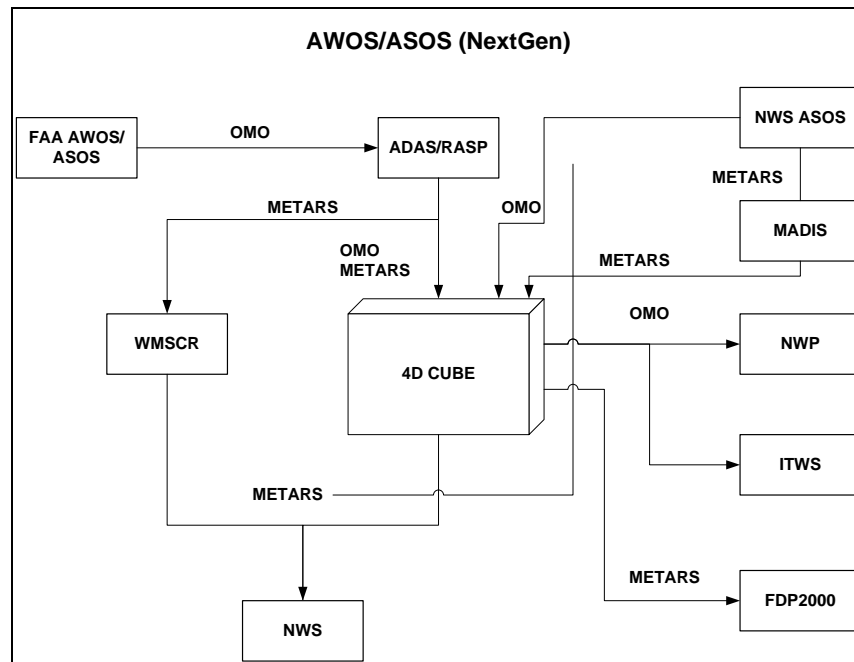
FAA AWOS and ASOS observations are provided to ADAS or the Regional ADAS Service Processor (RASP), where they are converted to METARs/SPECIs. The RASP makes AWOS/ASOS observations available to other FAA weather systems including ITWS, CIWS, and WARP. METARs/SPECIs generated by the RASP are provided to the WMSCR system which currently relays them to the FDP2000 system and to the NWS to be processed (conversion to international units) and retransmitted worldwide and to be used by the

NWS for inputs into numerical weather prediction models and for the generation of the Terminal Aerodrome Forecasts (TAFs).



In the NextGen timeframe, observations and METARS/SPECIs will be made available in the Wx Cube by RASP, where the NWP (providing current WARP/CIWS functionality) and ITWS will obtain these observations, and NWS and FDP2000 will obtain resultant METARS/SPECIs from the Wx Cube. WMSCR may also continue to distribute METARs from RASP. FAA efforts to define the future involvement of WMSCR are still underway, including whether NWS will obtain METARs from WMSCR or directly from the Cube.

NWS operated ASOSs will be used to generate METARS, which will be provided to the Cube via MADIS. Raw OMO data from NWS ASOS sites will also likely be provided to the Cube.



3.2 Lightning Data

3.2.1 Concept of Operations

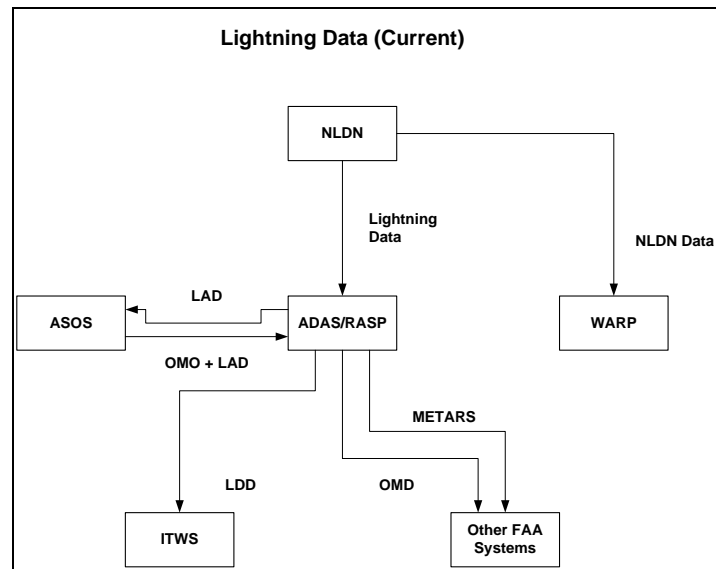
A vendor-operated National Lightning Detection Network (NLDN) system provides cloud-to-ground (CG) lightning strike data over the CONUS and offshore waters. The FAA also receives lightning data for Alaska from the Bureau of Land Management during the summer season, which is used by the WARP at the Anchorage ARTCC. The presence of lightning is confirmation of an area of deep convection (thunderstorms). The FAA uses lightning ground stroke data to indicate the presence of thunderstorms in three ways:

- As an indicator of thunderstorm activity in the proximity of the airport by adding lightning information in the remarks field of ASOS/AWOS surface observations
- An overlay to radar reflectivity
- A stand-alone graphical product

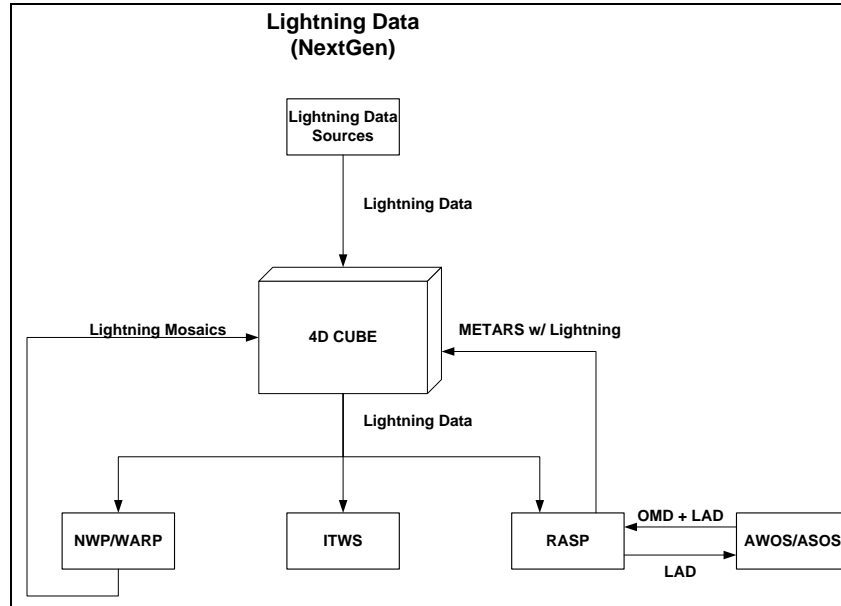
Lightning data enhances thunderstorm detection, especially in mountainous regions where terrain blockage may impede radar detection. It is used to correlate Cloud to Ground (CG) lightning strikes to ASOS/AWOS sites giving them a thunderstorm reporting capability.

3.2.2 Technology Architecture / Information Flows

The NLDN interfaces to the ADAS in the Air Route Traffic Control Centers (ARTCC), providing lightning detection data (LDD). ADAS sends the lightning data to the ASOS [to append to its METAR] and also appends lightning remarks to the AWOS METAR observation for improved reporting capability. ADAS also provides lightning detection data to ITWS. NLDN data is also provided directly to WARP.



In the NextGen timeframe, NWS or a 3rd party lightning data provider is expected to provide all lightning data via the Wx Cube. The NWP (WARP function) will use this data to produce lightning mosaics for use by FAA systems such as ERAM and TFMS. ITWS will also access lightning data from the Wx Cube. ADAS/RASP will obtain lightning data from the Wx Cube for use by ASOS/AWOS in appending observations and METARs with lightning information.



3.3 LLWAS

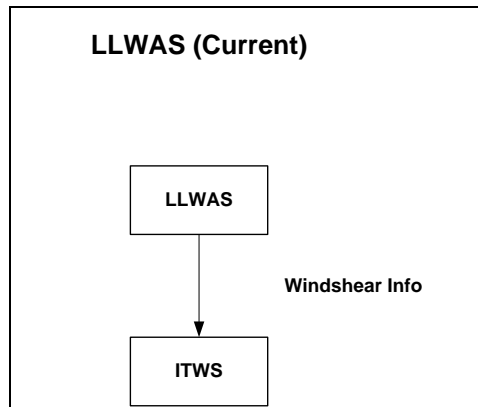
3.3.1 Concept of Operations

The Low Level Windshear Alert System (LLWAS) consists of wind sensors (anemometers) located around and just beyond the airport runway thresholds. Radio telemetry communicates the wind information to

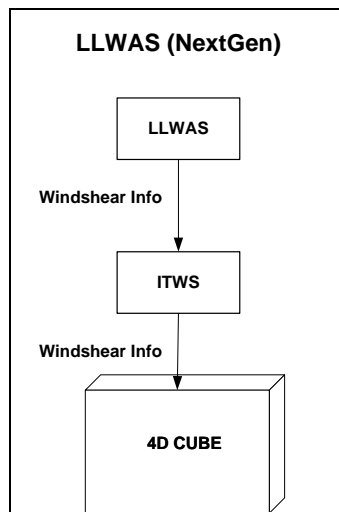
a central processor where calculations are performed to determine if hazardous wind shear conditions exist.

3.3.2 Technology Architecture / Information Flows

Wind shear alerts are provided to local controllers on a display in the tower cab via the ITWS system.



In the NextGen timeframe, LLWAs data will still likely be provided directly to ITWS, which will publish it to the Cube.



3.4 NEXRAD

3.4.1 Concept of Operations

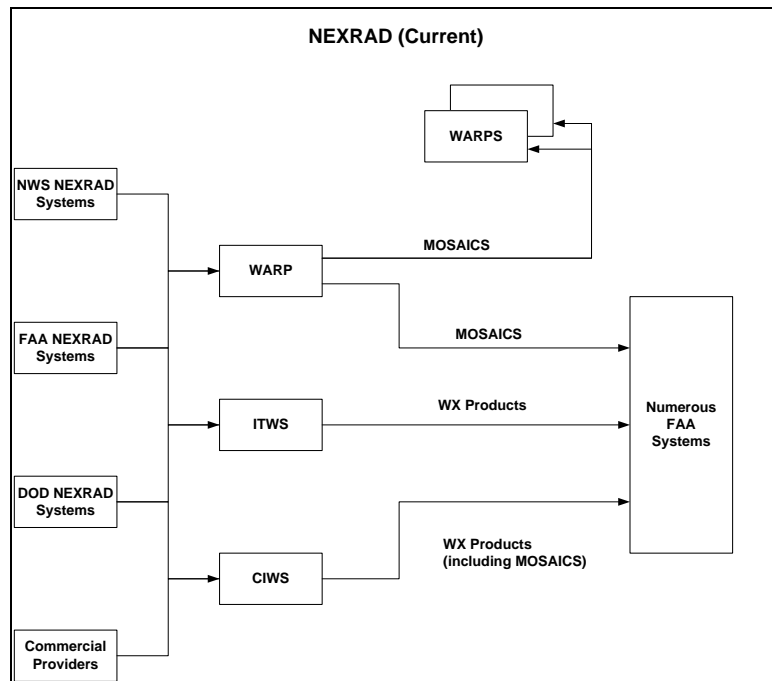
NEXRAD is a national network of Doppler weather radar systems, where each system consists of a sensor and processing subsystem(s) that detects, processes, and distributes precipitation and wind-related products. The NEXRAD radar system consists of two main components: a radar data acquisition subsystem (RDA) and a radar product generator (RPG). The FAA maintains its own systems, while the NWS maintains the majority of the rest of the systems.

Air Traffic controllers use displays of real-time NEXRAD reflectivity products on their scopes (Display Replacement System (DSR)) to provide weather advisories to pilots of hazardous convective weather along their flight paths and in the approach/departure corridors. The en route air traffic controller has the capability of displaying real-time NEXRAD data on their scopes as well. These data are received and processed through the WARP, which provides an ARTCC-scale mosaic of precipitation intensity. Traffic flow managers use similar products for strategic route planning on a national level so that the flow of air traffic can avoid areas of convective activity. Meteorologists at the CWSU, the Aviation Weather Center (AWC) in Kansas City, and the NWS Weather Forecast Offices also use NEXRAD products to evaluate potential weather hazards, provide aviation forecasts, and issue warnings and advisories.

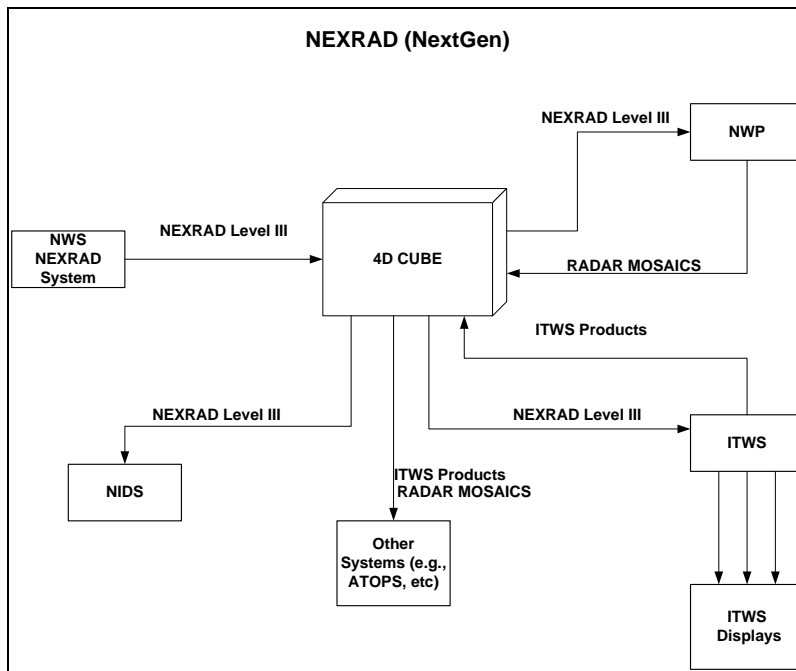
3.4.2 Technology Architecture / Information Flows

Most FAA users currently view NEXRAD products via the WARP and ITWS, which are directly connected to the radar product generator subsystem (RPG) for each NEXRAD site. Some FAA users acquire NEXRAD products from a commercial vendor.

Currently, CIWS interfaces with the NWS centralized communications facility to obtain base radar data, which is used to generate products displayed for traffic flow managers at 13 FAA facilities.



In the NextGen timeframe, NEXRAD data will be published via the Wx Cube and accessed by NWP, ITWS and the NAS Interface Display System (NIDS). NWP will generate radar mosaics and ITWS will generate other weather products derived from NEXRAD data for use by numerous FAA systems. NIDS will display radar graphically.



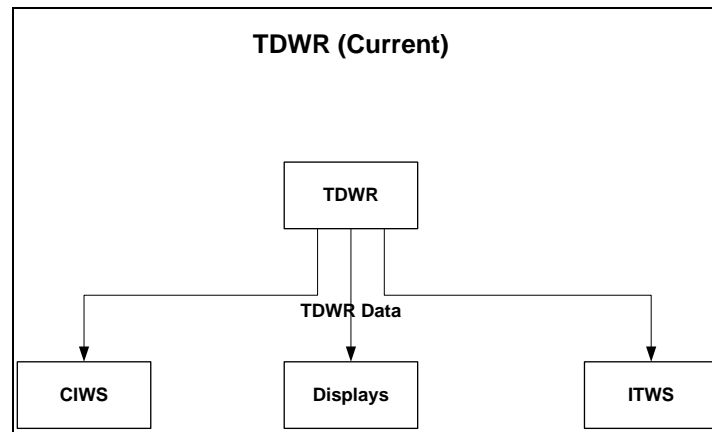
3.5 Terminal Doppler Weather Radar (TDWR)

3.5.1 Concept of Operations

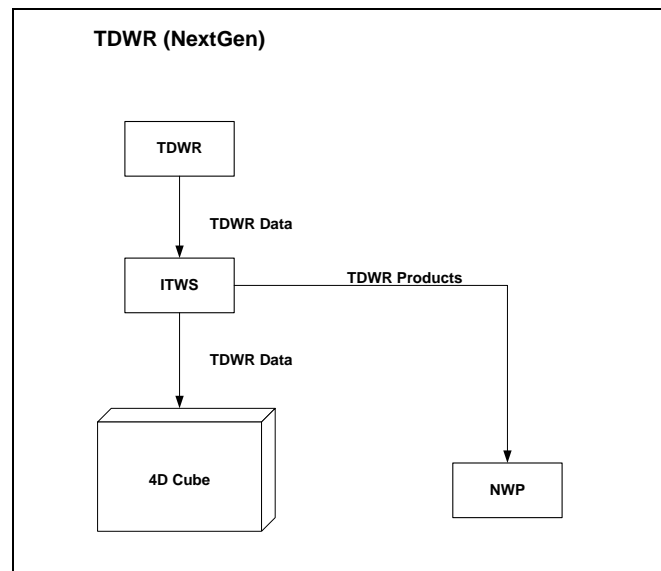
TDWR is an FAA weather radar system used to detect hazardous weather conditions such as wind-shear, micro-bursts and gust fronts, tornadoes, winds, heavy precipitation (inferring thunderstorms at an airport) impacting airport approach and departure paths. This information, in the form of an alert message, is provided to local controllers on a display in the tower cab. Tower and TRACON controllers use TDWR hazardous weather alerts and advance notice of changing wind conditions to redirect air traffic flow (reducing delays) and warn pilots of hazardous wind shear conditions along approach/departure corridors and runways. TDWR also provides a 10- and 20-minute prediction of gust front location and movement.

3.5.2 Technology Architecture / Information Flows

Currently, TDWR weather information is generated by the TDWR Radar Product Generator (RPG) and provided to air traffic personnel on displays at terminal facilities. TDWR radar data is provided to CIWS to be used in the generation of weather products. TDWR radar data is also used by ITWS in the determination of microburst detection and prediction, terminal winds, terminal weather test messages, gust front updates, storm motion, terminal convective weather forecast, and windshear.



In the NextGen timeframe, TDWR data will be provided to ITWS, which will collect and publish it the Cube, as well as use the radar data for the creation of various weather products for use by various FAA system, including NWP.



3.6 ASR-9

3.6.1 Concept of Operations

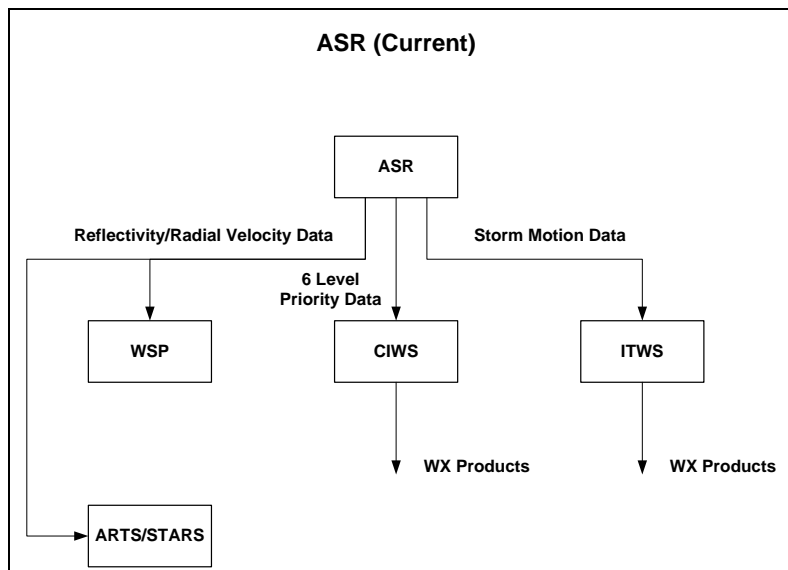
The ASR-9 Doppler radar's primary function is aircraft target detection but it also aids in weather detection. The ASR-9 weather channel outputs six-level precipitation reflectivity intensity and radial velocity data.

At some ASR-9 sites, tower and TRACON controllers access the ASR-9 weather channel via their Automated Radar Tracking System (ARTS) or Standard Terminal Automated Radar (STARS) displays to view a 6-level display of precipitation intensity, which provides information on hazardous weather conditions associated with thunderstorm activity.

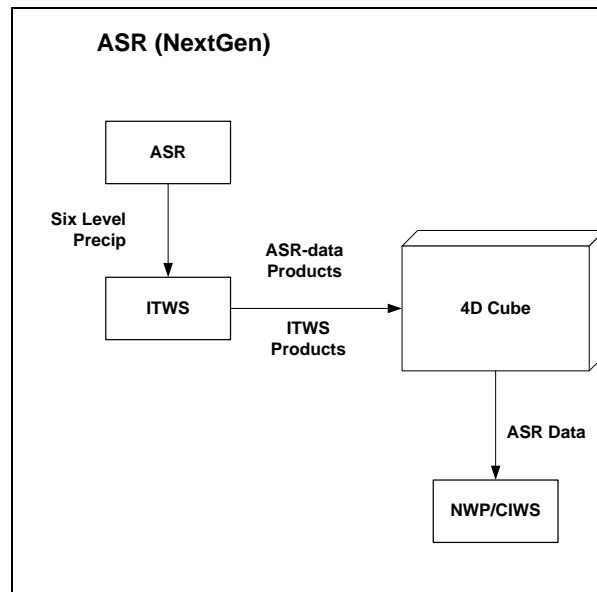
Reflectivity and radial velocity data from ASR-9 radars are provided to the ASR-WSP for the wind shear detection algorithm. The ASR-WSP provides terminal controllers with information on hazardous weather such as thunderstorms, low-altitude wind shear, microbursts, and gust fronts. The ASR-WSP improves terminal area flight safety by providing wind shear and microburst warnings. It also improves operations efficiency through coordination of near-term terminal area gust front predictions. The ASR-WSP is for airports with medium air traffic density.

3.6.2 Technology Architecture / Information Flows

Currently, ASR-9 reflectivity (6-level) data is provided to the ITWS. The reflectivity data is also provided to CIWS. Reflectivity and radial velocity data are provided to the ASR-WSP for the wind shear detection algorithm. At ASR-9 sites without the WSP capability, tower and TRACON controllers access the ASR-9 weather channel via their Automated Radar Tracking System (ARTS) or Standard Terminal Automated Radar (STARS) displays. This enables them to view a 6-level display of precipitation intensity, which provides information on hazardous weather conditions. Reflectivity and radial velocity data from ASR-9 radars are provided to the ASR-WSP for the wind shear detection algorithm.



In the NextGen timeframe, ASR data will be provided to ITWS, which will in turn publish the information to the Cube for use by such systems as NWP/CIWS and others, as well as create additional weather products from the ASR data.



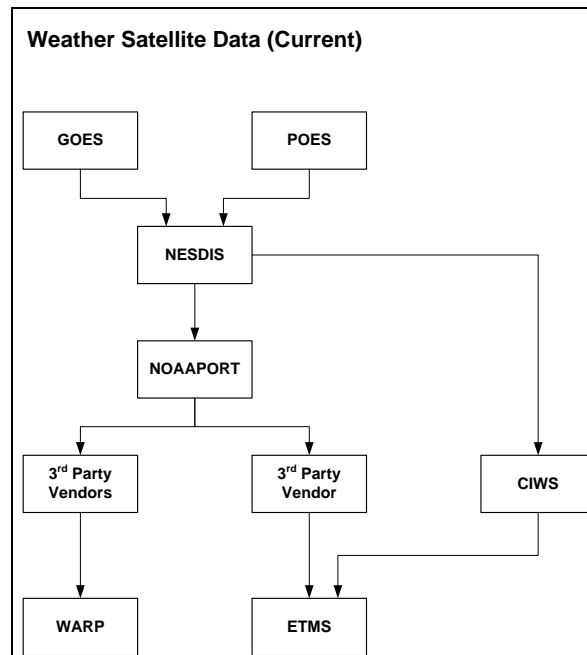
3.7 Weather Satellites

3.7.1 Concept of Operations

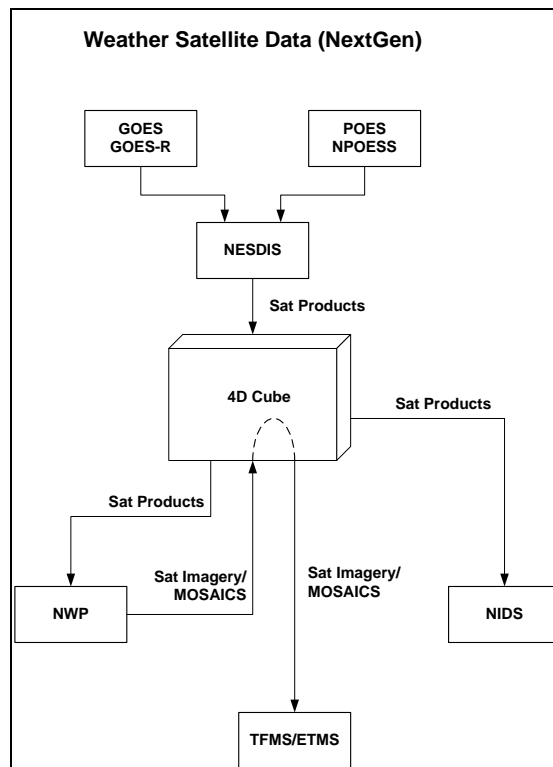
NOAA's operational weather satellite system is comprised of two types of satellites: Geostationary Operational Environmental Satellites (GOES) and polar-orbiting satellites. Data from the GOES is used for short-range warning and forecasting since it is available at very short intervals, while the polar orbiter data is used for longer-term forecasting as the satellite only passes the same point on the earth twice a day. Weather satellites transmit visible imagery for daytime observing, infrared photos for both day and night observing and water vapor imagery that identify locations of moist and dry air (important for thunderstorm forecasting). Satellite imagery and data are also detection sources of convection, volcanic ash, ceiling, and fog products used in flight planning.

3.7.2 Technology Architecture / Information Flows

Currently, satellite data is collected from NESDIS and disseminated via NWS's NOAAPORT and then is distributed to WARP and ETMS via third party vendors. CIWS is also receiving satellite data from NESDIS.



In the NextGen timeframe, all GOES and NPOESS satellite data will be available to the NWP and NIDS via the Cube. The NWP will create various products, including satellite mosaics for distribution to other systems including TFMS. NIDS will also display various satellite products.



3.8 MDCRS

3.8.1 Concept of Operations

ARINC's Meteorological Data Collection and Reporting System (MDCRS) service collects and disseminates real-time upper-air weather observations from participating airlines and forwards them in BUFR format to the National Weather Service (NWS)

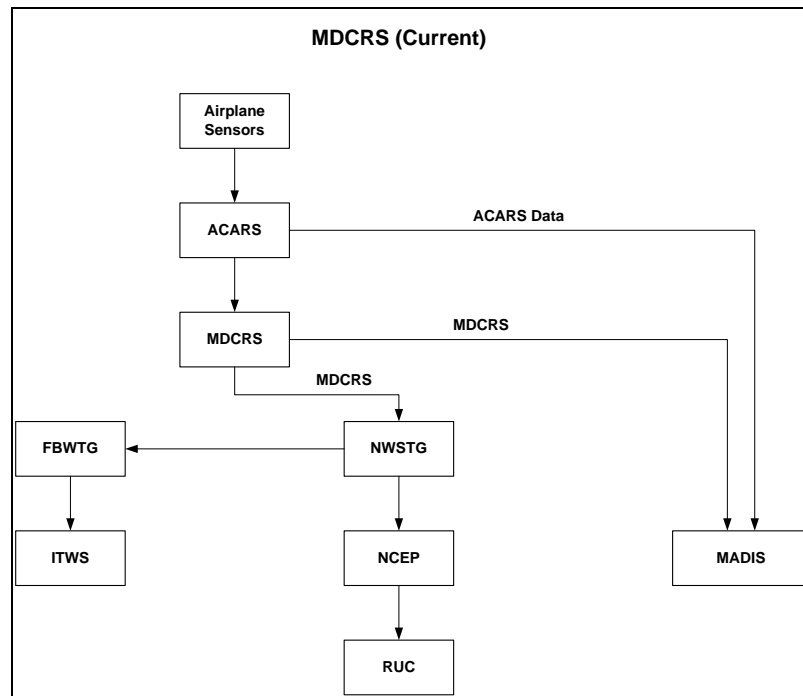
MDCRS is designed to support improved weather forecasting, particularly for upper-air wind and severe weather. MDCRS is an important data source for aviation weather forecasts. Some 1,600 aircraft from 8 commercial air carriers and cargo carriers (e.g., UPS) provide in-situ airborne observations to the FAA and NWS via ARINC's Aircraft Communications Addressing and Reporting System (ACARS). MDCRS provides the FAA and the NWS approximately 250,000 real-time, automated position and weather reports (winds and temperatures) per day. Data shows temperature inversions that forecast ceiling and visibility at airports, is useful in forecasting wind gusts & LLWS in terminal areas, and is used in the NCEP RUC model for aviation forecasts.

Data that is collected includes:

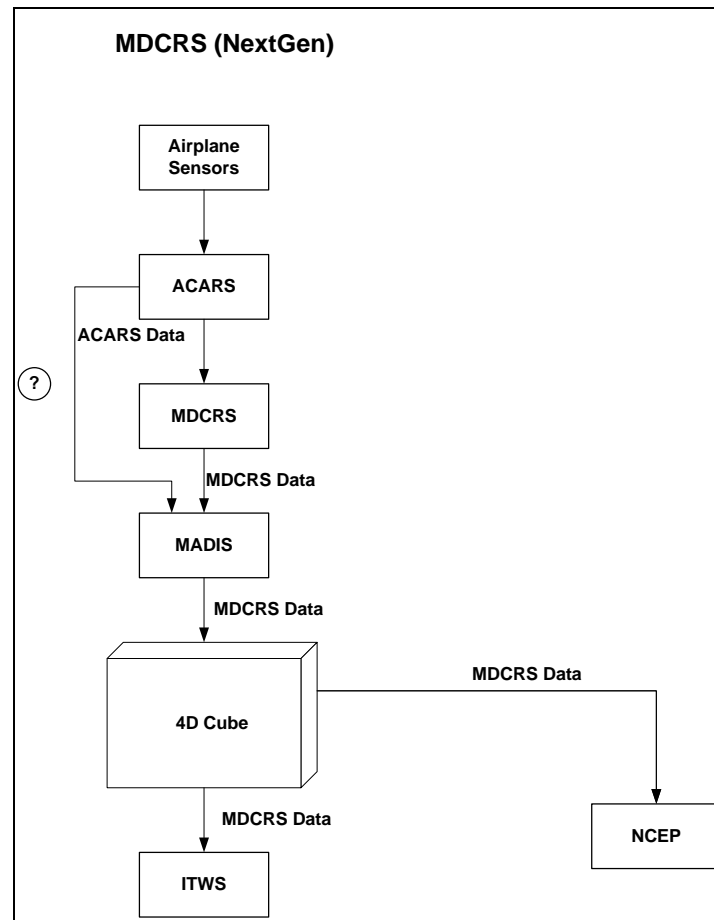
- Time of Observation
- Latitude
- Longitude
- Pressure Altitude
- Wind Direction
- Wind Speed
- Static Air Temperature
- Roll Angle Flag
- Phase of Flight (when available)
- Turbulence (when available)
- Icing (when available)
- Water Vapor Mixing Ratio (when available)

3.8.2 Technology Architecture / Information Flows

Observations are 'down linked' from the aircraft via ACARS, formatted, and then forwarded via the NWS and FAA Telecommunication Gateways to the ITWS. ITWS uses these observations for microburst prediction and terminal winds. NWS uses MDCRS data as input for weather forecast models (especially the Rapid Update Cycle (RUC)) to support aviation. ACARS data is also provided for redistribution via MADIS.



In the NextGen timeframe, MDCRS and ACARS data will be provided to MADIS. MADIS data, including MDCRS data, will then be available via the Cube. It is still under investigation whether only MDCRS will be provided via MADIS or will raw ACARS data will also be available via MADIS or some other mechanism. Distribution of MDCRS data will be TBD (via MADIS only?) ITWS will obtain MDCRS data directly from the Cube.



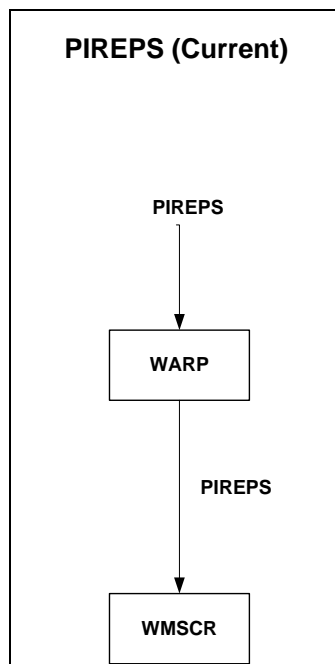
3.9 PIREPS

3.9.1 Concept of Operations

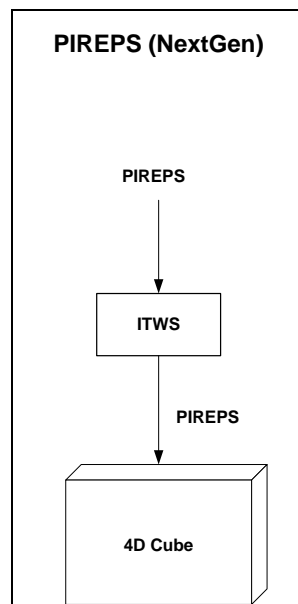
PIREPs are visual observations from pilots of weather aloft that include location, time, flight level, aircraft type, and at least one weather element encountered (such as intensity of turbulence and degree of icing). PIREPs may also report sky cover, flight visibility, temperature and wind. They are an important source of information for issuing and verifying the Airmen's Meteorological Information (AIRMET) and Significant Meteorological Information (SIGMET) forecasts.

3.9.2 Technology Architecture / Information Flows

Currently, PIREPS are collected and stored in the WARP systems and distributed via WMSCR to numerous FAA systems.



In the NextGen timeframe, PIREPS will be provided to the Wx Cube by ITWS, although this is still under review.



3.10 Rawinsonde

3.10.1 Concept of Operations

A rawinsonde, or balloon-borne instrument, is used to simultaneously measure and transmit meteorological data while ascending through the atmosphere. The instrument consists of sensors for the measurement of pressure, temperature and moisture as well as for the calculation of the horizontal

wind by tracking movement of the balloon. In the CONUS, there are 69 rawinsonde sites forming the national network, where observations are taken twice per day. The NWS is also responsible for 13 sites in Alaska, 1 in Puerto Rico, and 9 in the Pacific. Taken twice daily, rawinsonde data are used in numerical weather prediction models and often used for upper-air wind and temperature products.

3.10.2 Technology Architecture / Information Flows

In the NextGen timeframe, rawinsonde measurements will likely be provided via MADIS.

3.11 Weather Message Switching Center Replacement (WMSCR)

3.11.1 Concept of Operations

WMSCR is the gateway for the exchange of alphanumeric aviation weather information for aviation users. WMSCR collects, processes, stores and disseminates aviation weather products and information to various NAS systems, the airlines, commercial users, and international users.

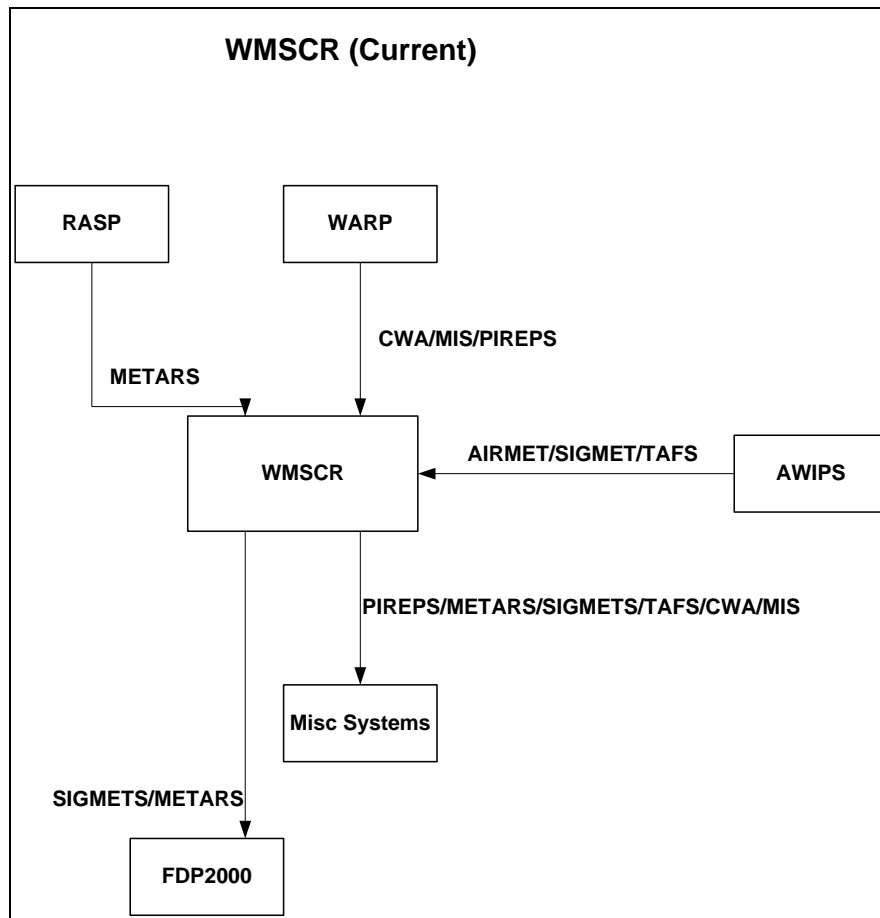
3.11.2 Technology Architecture / Information Flows

Currently, WMSCR obtains the following info for dissemination:

- MIS / CWS /CWA from CWSU meteorologists (via WARP)
- PIREPS (via WARP)
- METARs/SPECIs from RASP
- SIGMETs/AIRMETs/TAFs from NWS WFOs

WMSCR provides a number of systems weather data, including

- FDP2000 - provided SIGMETs, METARs, SPECIs



In the NextGen timeframe, WMSCR functionality is still under consideration by the FAA.

3.12 FAA Bulk Weather Telecommunications Gateway (FBWTG)

3.12.1 Concept of Operations

The FBWTG enables high-speed transmission of high priority weather information between the NWS and the FAA.

3.12.2 Technology Architecture / Information Flows

The FBWTG is located at the Air Traffic Control System Command Center (ATCSCC) in Herndon, Virginia. Upon receipt, information is disseminated to each CONUS ARTCC through satellite transmission and an interface with the WARP Weather Information Network Server (WINS). Information passed includes high-resolution, gridded model weather forecasts (CIP GRIB messages, GFS Thin Grids GRIB messages, NAM GRIB messages, UKMet GRIB messages), National Convective Weather Diagnostic (NCWD) and National Convective Weather Forecast (NCWF), MDCRS airborne observations, and AWC hazardous weather advisory products used in the NAS. ITWS also accesses RUC and MDCRS data via the FBWTG.

In the NextGen timeframe, the FBWTG will no longer exist and all communication with NWS / NOAA will be through the FAA Telecommunications Infrastructure (FTI) ED-8 Gateway. All data provided by NOAA today via FBWTG, will be published to the Cube by NOAA in the future.

3.13 Weather Information Network Server (WINS)

3.13.1 Concept of Operations

WINS provides local FAA systems with direct access to the wide variety of weather data resident on WARP.

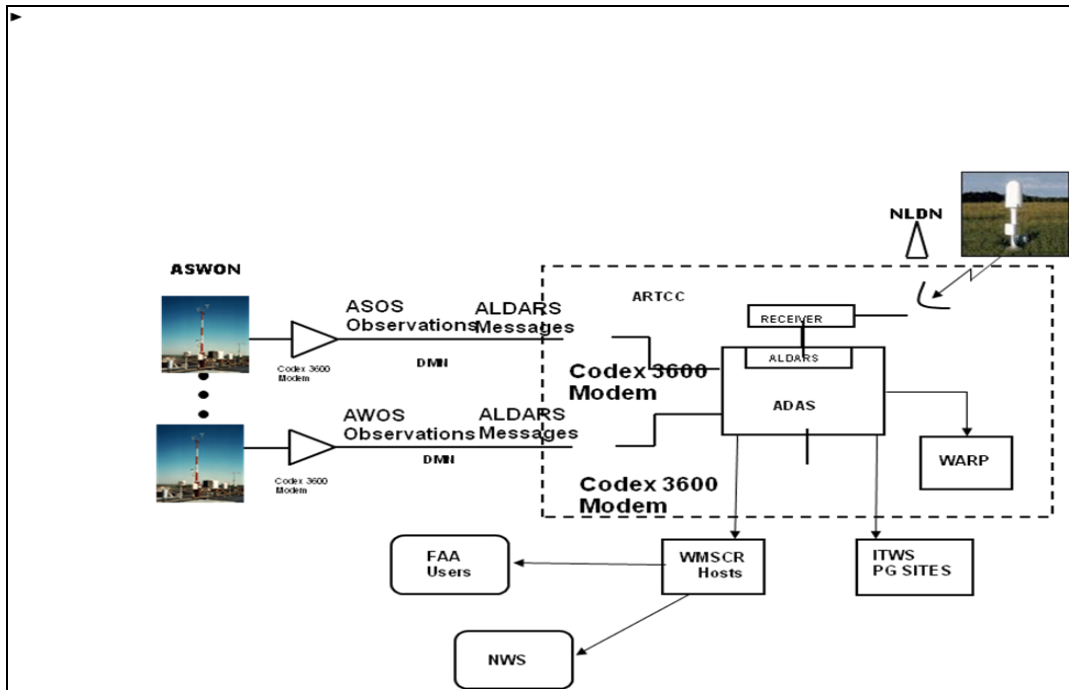
3.13.2 Technology Architecture / Information Flows

WINS is the dissemination module of the WARP system that provides an interface to various NAS users/systems that require weather data/products/information from WARP. In addition, it provides for WARP to WARP connectivity for exchange of weather information between the ARTCCs.

As WARP is being replaced in the NextGen timeframe by the NWP, so too will WINS.

3.14 ADAS/RASP

The ADAS at each CONUS ARTCC collects and bundles automated surface observations from the FAA AWOS and ASOS within the ARTCC boundaries and distributes them to the local WARP and WMSCR system, the latter for relay to the NWS. A software routine in ADAS (the Automated Lightning Detection and Reporting System (ALDARS)) receives lightning stroke information (latitude and longitude) and relays the stroke position to the ASOS, which appends the surface observation with the appropriate thunderstorm proximity indication. The ALDARS appends the lightning information to the AWOS and sends the appended observation back to the AWOS for broadcast. The functionality performed by ADAS/RASP with respect to surface observations and lightning data is described in those respective ASOS/AWOS and LLWAS sections above.



3.15 Flight Information Service (FIS)

3.15.1 Concept of Operations

The FAA implemented the national FIS service to assist air traffic controllers and Flight Service specialists in alerting pilots of hazardous weather and also to transmit routine and advisory weather information to pilots in flight. FIS data consists of non-control, advisory information that pilots need to operate more safely and efficiently. Textual and graphic FIS products include NOTAMs, Special Use Airspace (SUA) data, and basic weather updates. As a vendor-provided service, FIS uses a form of Data Link (FIS-DL) that allows pilots in-flight access to information on rapidly changing weather conditions. This allows them to request dynamic changes to their flight plan to avoid hazardous weather while optimizing their fuel consumption and flight time.

3.16 Integrated Terminal Weather System (ITWS)

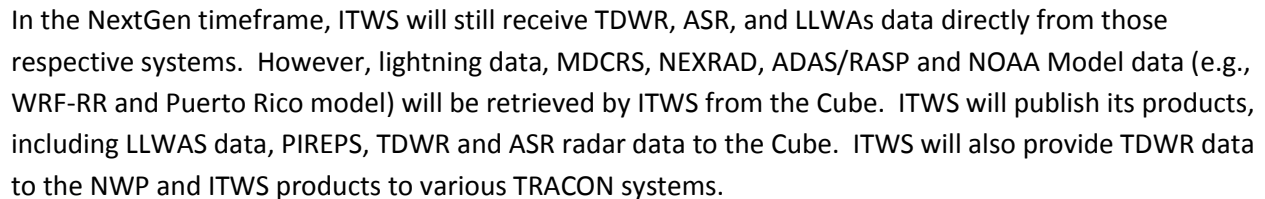
3.16.1 Concept of Operations

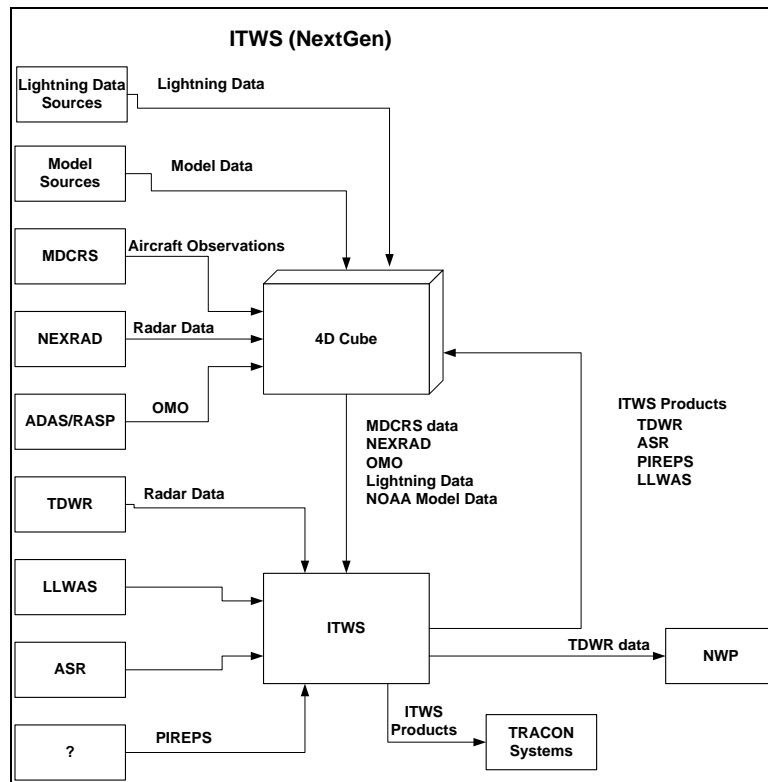
ITWS enhances NAS capacity by improving efficiency as it displays convective weather and associated hazards at selected NAS pacing airports to traffic managers and AOC dispatchers. ITWS provides a real-time picture of aviation-impacting weather to traffic managers at ARTCCs, the ATCSCC, and large TRACONs via an ITWS Situation Display (SD) so that they can track storm activity at major NAS airports and facilitate the coordination of traffic flow to mitigate the effect of weather on NAS operations on airport acceptance rates. This promotes common situational awareness, which is absolutely crucial to the collaborative decision making process that is necessary to reduce weather-related delays.

With its microburst prediction capability, ITWS also increases aircraft safety on runways and in approach/departure corridors at NAS pacing airports by providing controllers and pilots with advance

ITWS improves weather support to the busiest NAS airports and traffic managers can assess the real-time impact of convective weather by planning for convective weather. Such advance planning improves system capacity by reducing weather-related delays at these high capacity airports where the vast majority of NAS delays are realized.

ITWS ingests numerous sources of data—local surface ASOS observations from ADAS, MDCRS aircraft observations, lightning stroke information, NEXRAD products, reflectivity data from the ASR-9 weather channel, wind shear information (LLWAS and TDWR), gridded model forecast data from the NWS, and other model data from WARP. This enables ITWS to generate many terminal-specific products tailored for air traffic controllers and traffic managers. ITWS products to the data stream flowing to airline operations centers and pilots.





3.17 Weather and Radar Processor (WARP)

3.17.1 Concept of Operations

WARP is the weather product generator for en route operations. It provides weather radar information to air traffic controllers, traffic management specialists, and to area supervisors, as well as CWSU meteorologists at the ARTCCs. Traffic managers use this information to plan for routing or rerouting of air traffic to increase the safety, efficiency and capacity of the NAS. Air traffic controllers use NEXRAD radar mosaics received from WARP for more tactical applications, such as advising pilots in their sector of weather hazards along the flight path, and if requested, providing vectors around this weather. Additionally, the CWSU meteorologist briefs traffic managers and weather coordinators about potential impacts of severe weather on NAS capacity. This shared situational awareness of impacting weather facilitates the efficiency of traffic flow and enables traffic managers to minimize weather-related delays.

WARP has four basic functions:

- Receives NEXRAD radar data and products, processes the data and provides mosaic products for air traffic controllers via the DSR
- Acts as a meteorologist workstation for CWSU personnel
- Distributes and displays weather data within the ARTCC by means of briefing terminals
- Provides weather data to other NAS systems through the WINS

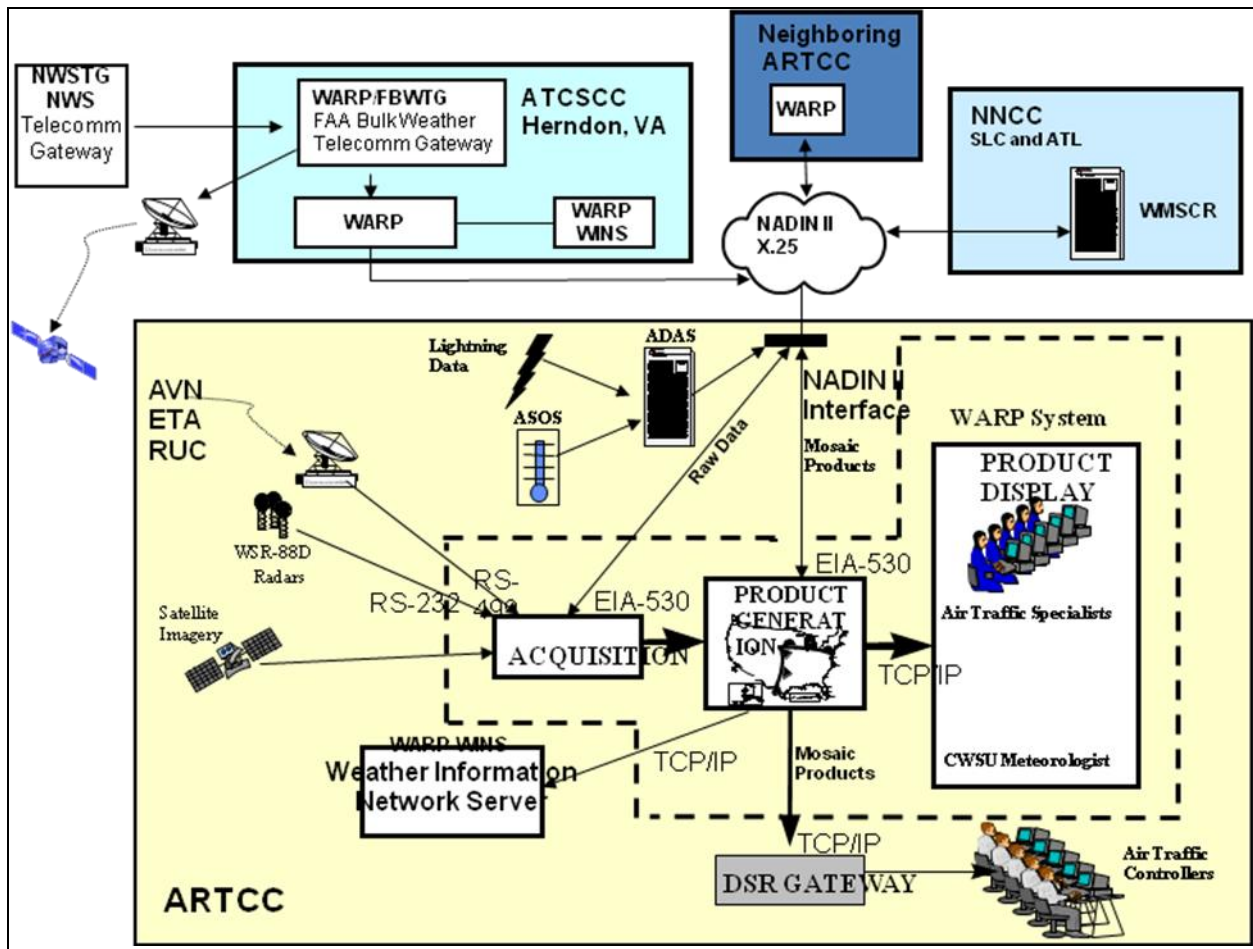
3.17.2 Technology Architecture / Information Flows

WARP receives aviation observations and products from multiple sources:

- Surface observations and lightning data via ADAS
- Weather radar information from NEXRAD
- Weather products from NWS and via the Harris Weather Data Service (HWDS)
- Lightning data from various 3rd party vendor sources
- NWS gridded diagnostic and model forecast products via the FBWTG and satellite feeds
- Text products (including PIREPs) via WMSCR
- Gridded products (convection, icing, and turbulence) from the AWC

The ATCSCC WARP disseminates a variety of National Mosaic data (including composite reflectivity, Base Reflectivity, Echo Tops, Vertically Integrated Liquid) to WARP. This is part of the WARP to WARP functionality that is included in the WARP Weather Information Network Server (WINS). Additionally, WARP provides the following:

- To ATOPS – GRIB-based model data (GFS, UKMET) and reflectivity mosaics
- To DOTS – GRIB-based model data (GFS)
- To FDP2000 – GRIB-based model data (NAM V,R)
- To URET/DSR – GRIB-based model data (RUC W)
- To CAPER - GRIB-based model data (RUC Q)
- Via WMSCR – CWA, CWS/MIS, PIREPS
- To ERAM - Reflectivity mosaics
- MEARTS - Reflectivity mosaics
- To ITWS – Model data



In the NextGen timeframe, the WARP function will be superseded by the NWP which will obtain most of its required input data from the Cube.

3.18 Corridor Integrated Weather System (CIWS)

3.18.1 Concept of Operations

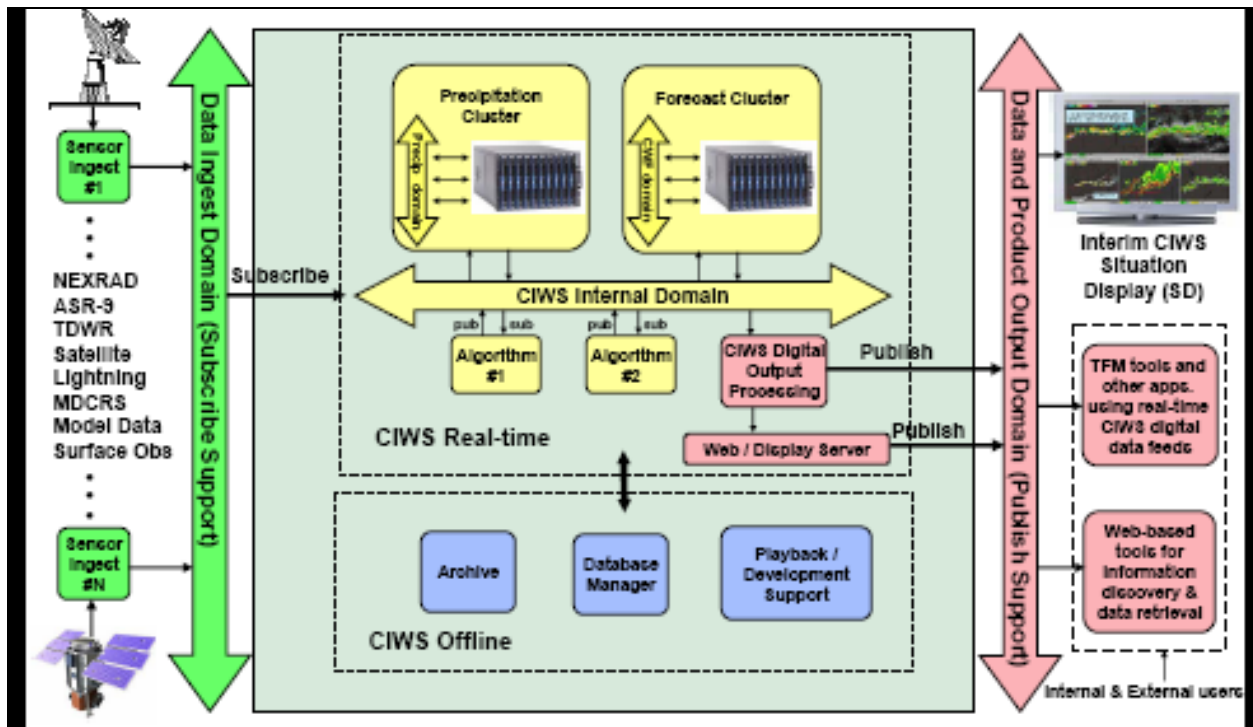
CIWS is a web-based, nation-wide operational decision support tool to improve traffic flow management. CIWS provides traffic flow managers with comprehensive convective weather information needed for tactical modifications (0-2 hours). CIWS provides information on the current convective weather situation as well as fully automated forecasts of convection and attributes, e.g., Echo Tops, out to 2 hours. CIWS collects various data, then processes, generates, displays, and distributes convective (thunderstorm) weather forecast products to traffic managers at the Air Traffic Control System Command Center (ATCSCC), numerous Air Route Traffic Control Center (ARTCC) facilities, large Terminal Radar Approach Control (TRACON) facilities, and some large airports. By concentrating its two-hour forecast product over busy National Airspace System (NAS) corridors, CIWS enables traffic managers to plan for routing/rerouting due to impacts on the airspace from major thunderstorm disruptions.

3.18.2 Technology Architecture / Information Flows

The CIWS receives weather data from multiple sensors and distributes processed information to NAS traffic managers via Situation Displays. More specifically, it obtains information as follows:

- Canadian weather radar
- ASR radar data
- TDWR radar data
- Surface observations from MADIS
- Satellite weather products from GOES
- NEXRAD radar data
- Model data from NOAA (RUC)
- Surface observations from ADAS/RASP

The resultant weather products are provided to the TFMS/ETMS, as well as other external Web-based users.



Source: Lincoln Labs, Orlando NBAA meeting 11/2005

In the NextGen timeframe, the CIWS function will be superseded by the NWP which will obtain most of its required input data from the Cube.

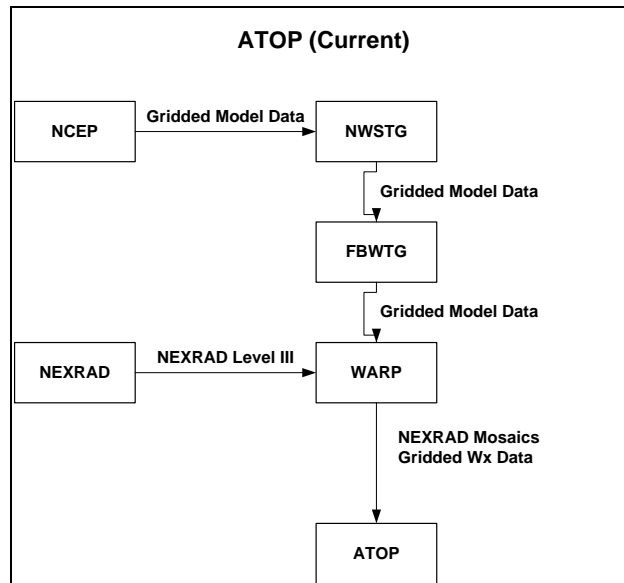
3.19 Advanced Technology and Oceanic Procedures (ATOP)

3.19.1 Concept of Operations

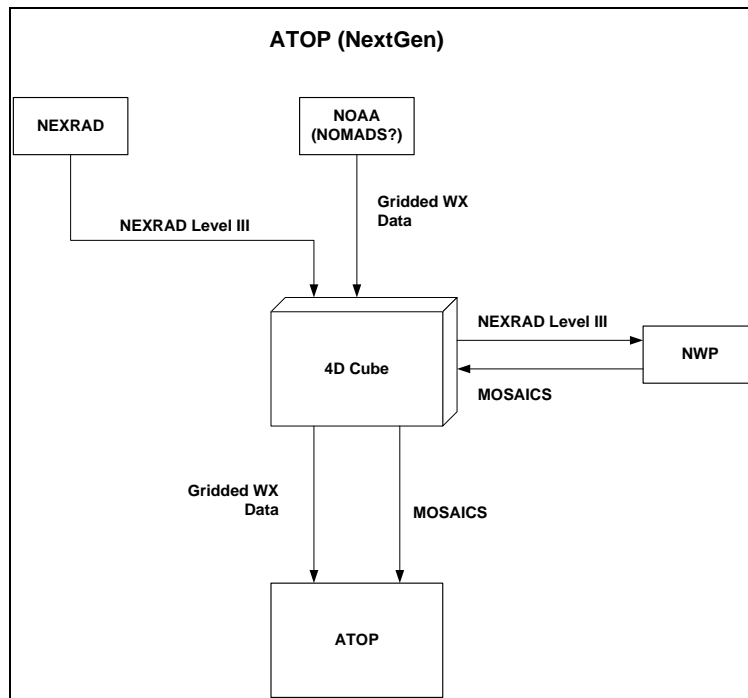
Oceanic controllers use ATOP to enhance situational awareness. ATOP collects, manages, and displays oceanic air traffic data and integrates weather products with processed flight data and radar data near CONUS shores.

3.19.2 Technology Architecture / Information Flows

Currently, WARP provides gridded weather data (i.e., winds and temperatures) via an interface to ATOP. WARP obtains the data from NWS via the FBWTG. Near the coasts of the U.S., NEXRAD imagery (mosaics) is provided to oceanic sector controllers via a separate WARP to ATOP interface. WARP obtains the NEXRAD Level III data required to generate the mosaics directly from the NEXRAD system.



In the NextGen timeframe, gridded weather model data (UKMET and GFS Thin Grid GRIB data) from NWS (and other sources) will be obtained directly from the Cube by ATOPs. Radar mosaics created by NWP from NEXRAD Level III radar data, will also be available from the Cube.



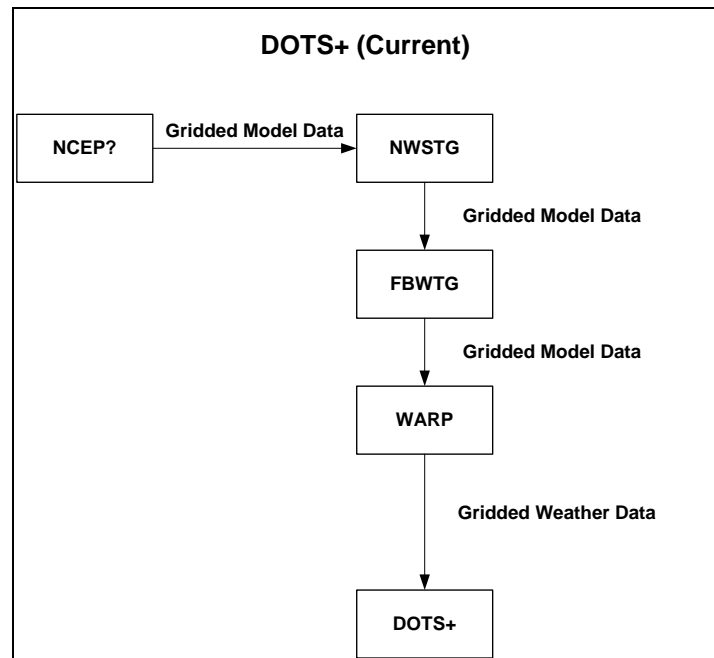
3.20 Dynamic Ocean Track System Plus (DOTS+)

3.20.1 Concept of Operations

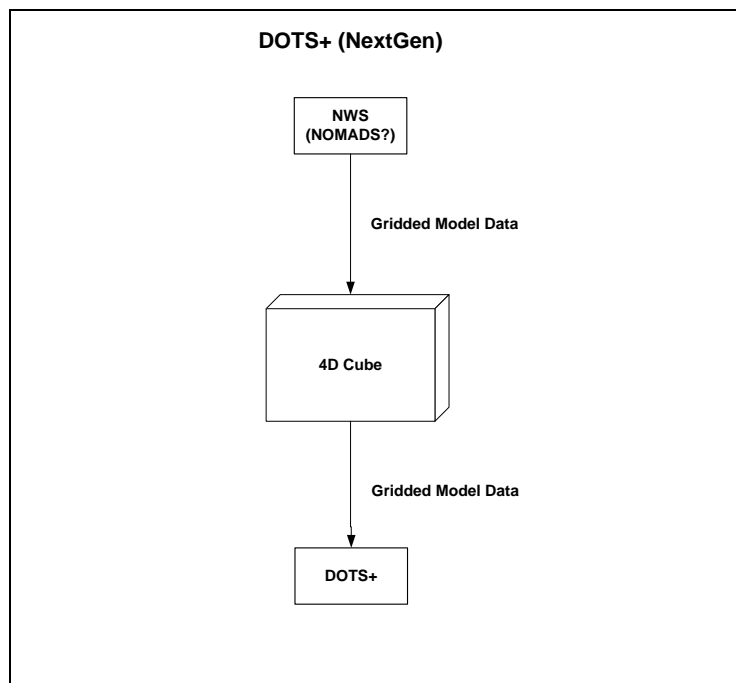
DOTS Plus assists oceanic air traffic planning and management functions by integrating weather information, then generating flexible oceanic organized tracks optimized for flight time and fuel efficiency using forecast winds aloft modeling that incorporates oceanic separation requirements. DOTS Plus uses accurate forecasts of winds and temperatures, as well as convective weather position information (i.e., convective products) to optimize oceanic route selection. The DOTS Plus Server at the ATCSCC receives data twice daily and distributes it to oceanic ARTCCs.

3.20.2 Technology Architecture / Information Flows

Currently, WARP provides gridded weather data (i.e., winds and temperatures) via an interface to DOTS+. WARP obtains the data from NWS via the FBWTG.



In the NextGen timeframe, GFS Thin Grid gridded weather model data from NWS (and other sources) will be obtained directly from the Cube by DOTS+.



3.21 Flight Data Processor 2000 (FDP2000)

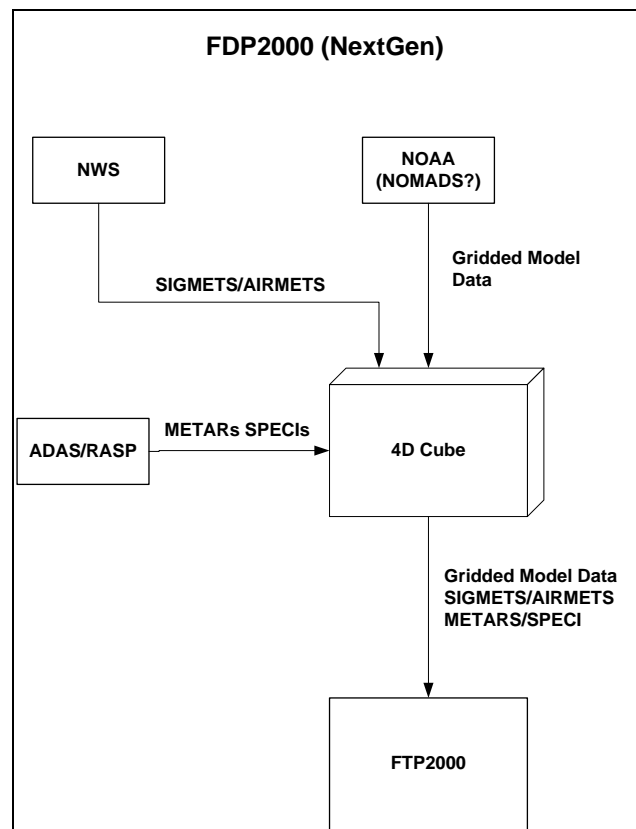
3.21.1 Concept of Operations

The Flight Data Processing 2000 (FDP2000) system replaced the oceanic flight data processing capability previously provided by Offshore Computer System (OCS) at the Anchorage Air Route Traffic Control Center (ARTCC). The added capabilities include winds aloft modeling for improved aircraft position extrapolation accuracy, and support of Air Traffic Services Inter-facility Data Communications Systems (AIDC) ground-to-ground data link with compatible Flight Information Regions (FIRs). FDP2000 provides flight data to the Microprocessor-En Route Automated Radar Tracking System (Micro-EARTS) radar data processing system.

3.21.2 Technology Architecture / Information Flows

Currently, FDP2000 obtains model data (GRIB-based NAM V and N) from WARP, and SIGMETs, AIRMETs, METARS, SPECIs, and other weather products via WMSCR.

In the NextGen timeframe, FDP2000 will obtain all its required data directly from the Cube.



3.22 CAASD Analysis Platform for En Route (CAPER)

3.22.1 Concept of Operations

CAPER is a decision support tool used to determine how much weather – and at what level – does it take to impact the intended flow of traffic.

3.22.2 Technology Architecture / Information Flows

Currently, CAPER obtains model data (GRIB-based RUC Q) from WARP.

In the NextGen timeframe, CAPER will obtain all its required data directly from the Cube.

3.23 User Request Evaluation Tool (URET) or Enhanced Traffic Management System (ETMS) ERAM/URET

3.23.1 Concept of Operations

ERAM supports the following functionality:

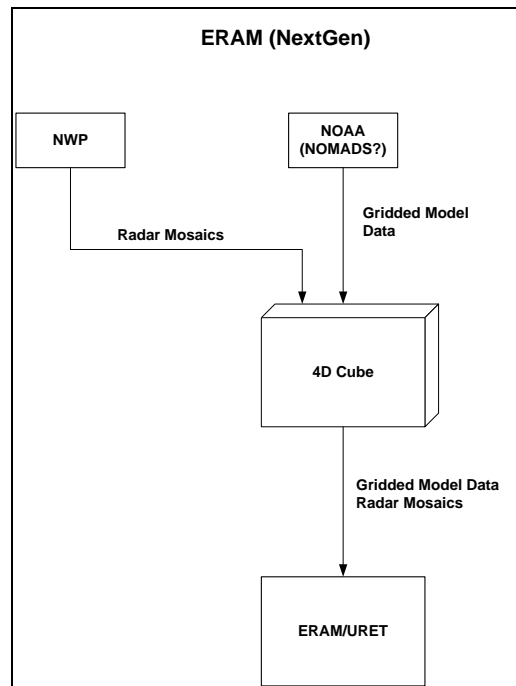
- Provides information security and streamlines traffic flow at international borders
- Processes flight radar data
- Provides communications support
- Generates display data to air traffic controllers
 - The display system provides real-time electronic aeronautical information and efficient data management.
- Provides a fully functional backup system, precluding the need to restrict operations in the event of a primary failure
 - The backup system provides the National Transportation Safety Board-recommended safety alerts, altitude warnings and conflict.
- Improves surveillance by using a greater number and variety of surveillance sources

URET uses RUC wind and temperature data to optimize its algorithm that calculate aircraft trajectories. URET combines real-time flight plan and radar track data with site adaptation, aircraft performance characteristics, and winds and temperatures aloft to construct four dimensional flight profiles, or trajectories, for pre-departure and active flights. For active flights, it also adapts itself to the observed behavior of the aircraft, dynamically adjusting predicted speeds, climb rates, and descent rates based on the performance of each individual flight as it is tracked through en route airspace, all to maintain aircraft trajectories to get the best possible prediction of future aircraft positions. URET uses its predicted trajectories to continuously detect potential aircraft conflicts up to 20 minutes into the future and to provide strategic notification to the appropriate sector. URET enables controllers to "look ahead" for potential conflicts through "what if" trial planning of possible flight path amendments. URET enables controllers to accommodate user-preferred, off-airway routing to enable aircraft to fly more efficient routes, which reduce time and fuel consumption.

3.23.2 Technology Architecture / Information Flows

Currently, URET obtains upper air model data (GRIB-based RUC W) from WARP. ERAM obtains reflectivity mosaics from WARP.

In the NextGen timeframe, the combined ERAM/URET will obtain all required weather data directly from the Cube. WRF-RR model data will be provided to the Cube by NOAA and reflectivity mosaics will be provided to the Cube by the NWP.



3.24 Micro En Route Automated Radar Tracking System (MEARTS)

3.24.1 Concept of Operations

The Microprocessor-En Route Automated Radar Tracking System (MEARTS) is a radar processing system implemented with commercial off-the-shelf (COTS) equipment, for use in the Anchorage ARTCC. It provides a mosaic display of traffic and weather using long- and short-range radars. The MEARTS interfaces with multiple types of displays, including the flat panel Display System Replacement.

3.24.2 Technology Architecture / Information Flows

Currently, MEARTS obtains WARP-generated reflectivity mosaics directly from WARP.

In the NextGen timeframe, MEARTS will obtain this information directly from the Cube, which will be provided to the Cube by the NWP.

3.25 Traffic Flow Management System/Enhanced Traffic Management System (TFMS/ETMS)

3.25.1 Concept of Operations

The TFMS is the principle component of the TFM infrastructure used by the FAA and NAS stakeholders to predict demand, identify constraints, mitigate delays and maintain common situation awareness. TFMS is based on an open architecture platform supporting the integration of TFM subsystems, facilitating integration with other domains, and supporting responses to new initiatives. In addition to improving development bandwidth, TFMS establishes a platform that is sustainable and scalable for the next decade and beyond. TFMS displays certain weather products (CCFP, NCWF, and Radar mosaics) onto the Traffic Situation Display function of the TFMS.

3.25.2 Technology Architecture / Information Flows

In the NextGen timeframe, the TFMS/ETMS will obtain convective weather forecasts generated by NWP (CIWS) as well as other required weather products directly from the Cube.

3.26 ASOS Controller Equipment / Integrated Display System (ACE IDS)

3.26.1 Concept of Operations

ACE-IDS is a network of individual workstations that provide Air traffic Control Specialists with weather data in the TRACON facility. It offers the display of numerous weather and non-weather products. ACE-IDS allows data from a wide variety of internal and external sources to be consolidated on screen in many combinations and formats for easy access within a graphical user interface. Reference data, such as charts, maps, approach plates, procedures, etc. are integrated with real-time data collected by interfaces to other systems. ACE-IDS users can be alerted automatically to changes in critical information. Integrated data formats eliminate the need for multiple system displays at each console, freeing space while creating a single focal point at each controller's console for obtaining information.

3.26.2 Technology Architecture / Information Flows

ACE-IDS servers and workstations running the Windows-NT operating system are linked via TCP/IP communications protocol for data dissemination over wide area networks.

ACE-IDS interfaces with the following systems:

- ASOS
- AWIPS
- Digital Altimeter Setting Indicator (DASI)
- Flight Input/Output (FDIO)
- LLWAS
- Runway Visual Radar
- TDWR
- SA-IDS

3.27 NextGen Weather Processor (NWP)

3.27.1 Concept of Operations

In the NextGen timeframe, the NWP is envisioned to combine and replace the current CIWS and WARP functionality. The NWP will generate reflectivity mosaics and will create several convective weather forecast products. However, whereas the WARP currently serves as a distributor of numerous externally obtained weather products, in the NextGen timeframe, users of these externally obtained products will get them directly from the Cube.

3.27.2 Technology Architecture / Information Flows

The NWP will obtain most of the necessary weather data directly from the Cube. This data will include:

- For CIWS replacement functionality
 - Lightning data
 - One minute observations ADAS/RASP
 - Surface observation from MADIS
 - GOES IR and VIS products from NOAA
 - NEXRAD Level III products from NOAA
 - Canadian radar data (CONVOL)
 - ASR data and TDWR data from ITWS
 - RUC (WRF-RR) model data from NOAA
- For WARP replacement functionality
 - Lightning data
 - NEXRAD Level III products from NOAA
 - CWSU products (CWA/MIS) via N-AWIPS
 - Various NOAA products and forecasts
 - CIP
 - GFS model data
 - NAM model data
 - UKMET model data (from NOAA TBD?)
 - NCWP
 - NCWF
 - RUC Q, RUC W model data
 - HRRR model data

The NWP will publish reflectivity mosaics and several convective weather forecast products directly to the Cube. Potential users of this data include:

- TFMS/ETMS (convective weather forecasts)
- ATOP (reflectivity mosaics)
- ERAM (reflectivity mosaics)
- MEARTS (reflectivity mosaics)
- NIDS (WARP image products, mosaics)

- External users (convective weather forecasts and reflectivity mosaics)

3.28 Aviation Decision Support Tools (DST)

Numerous decision support tools are being considered for use in the NextGen aviation environment. The Weather Integration Plan document addresses these potential tools and the likely weather data needed to support them. As these DSTs become realities, additional analysis will be necessary to determine the specific weather data needed, their sources, and the associated requirements associated with the data. From these analyses, additional Cube requirements most certainly will evolve.

3.28.1 Weather Enterprise Decision Support Service (WEDSS)

One DST being considered is the Weather Enterprise Decision Support Service (WEDSS). WEDSS is intended to provide information required by users that cannot be directly extracted from the 4-D Wx SAS grid point data; information such as density altitude, maximum daily temperature over the last 24 hours, or altimeter settings. For example, the requirement for specifying when a weather phenomenon impacts operations (e.g., time when precipitation will begin or end at an airport) depends on the users' operational needs. The most appropriate and efficient method for supporting such a large range of operational uses of cube data is to establish a weather enterprise service that can examine the 4-D Wx SAS grid values and provide tailored information to the user. Users or a function within the weather enterprise would be required to extract the needed information from the 4-D Wx SAS via the WEDSS. Examples of functions performed by WEDSS may include determining vertical extent, horizontal extent, layer thickness, beginning time, ending time, and duration of weather elements.

3.29 NAS Interface Display System (NIDS)

NIDS is intended to replace the existing display capabilities of the WARP Briefing Terminal. This includes the display of the following data, all accessed from the Cube in the NextGen timeframe:

- WARP textual products
- WARP image products
- NWS graphical product data
- NEXRAD radar data
- NWP-generated mosaics
- Satellite imagery data

3.30 Consolidated Storm Prediction for Aviation (CoSPA)

The development of Consolidated Storm Prediction for Aviation (CoSPA) has been initiated by the Federal Aviation Administration (FAA) in order to replace several currently available weather forecast products by a single forecast to be used in all government-provided aviation weather systems. CoSPA will embody the best techniques available today, with an open modular architecture that enables easy exchange of algorithm modules, as new or upgraded techniques become available. CoSPA will build upon a mixture of observation-based expert systems and numerical weather prediction model to provide seamless 0 – 8 h forecasts of convective hazards and heavy snowfall. An initial forecast demonstration experiment of a CoSPA prototype is underway. CoSPA is a collaborative effort between the National Center for Atmospheric Research (NCAR), Massachusetts Institute of Technology (MIT)

Lincoln Laboratory, and the NOAA Earth System Research Laboratory (ESRL) under sponsorship of the FAA.

The goals of COSPA include:

- Implement research aimed at improving observation, forecasts, and weather suitable for use by ATM, and flight deck decision support tools
- Implement technologies which allow user access without user detailed knowledge of source or unique/proprietary interfaces
- Implement standardized development and implementation methods which allow for rapid update of capabilities
- Develop the authoritative weather data repository—known as the 4-dimensional data cube—which will provide net-centric access by system users to consistent, tactical-and strategic-level weather information
 - Use of SWIM for core services
 - CoSPA forecasts to be available via the cube
- Implement the NextGen Initial Operating Capability leveraging technologies from the research, commercial vendor and other Government sources

Intended data formats include:

- NetCDF4/HDF5 for gridded data products
- XML for non-gridded products
- ISO data model foundational components

Intended data dissemination services include:

- OGC Sensor & Data Discovery catalog
- OGC Web Coverage Service (gridded data)
- OGC Web Feature Service (non-gridded data)
- JMBL/JET Node

Intended communication approaches include:

- CoSPA is collaborating with NNEW/SWIM
- CoSPA will adopt NNEW/SWIM as they evolve
 - Writing data adapters to convert native formats to/from NetCDF4/HDF5
 - LDM used for data dissemination in the meantime